S. HRG. 100-816

GLOBAL CHANGE RESEARCH

HEARING

BEFORE THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDREDTH CONGRESS

SECOND SESSION

ON

GLOBAL CHANGE RESEARCH AND

S. 2614

TO AMEND THE NATIONAL SCIENCE AND TECHNOLOGY POLICY, ORGANIZATION, AND PRIORITIES ACT OF 1976 IN ORDER TO PROVIDE FOR IMPROVED COORDINATION OF NATIONAL SCIENTIFIC RESEARCH EFFORTS AND TO PROVIDE FOR A NATIONAL PLAN TO IMPROVE SCIENTIFIC UNDERSTANDING OF THE EARTH SYSTEM AND THE EFFECT OF CHANGES IN THAT SYSTEM ON CLIMATE AND HUMAN WELL-BEING

JULY 13, 1988

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NATIONAL GLOBAL CHANGE RESEARCH PLAN

WEDNESDAY, JULY 13, 1988

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, D. C.

The Committee met, pursuant to notice, at 9:34 a.m., in Room SR-253, Russell Senate Office Building, Hon. Ernest F. Hollings, Chairman, presiding.

Staff members assigned to this hearing: Penny Dalton, professional staff member; and Sherman Joyce, minority staff counsel.

OPENING STATEMENT BY THE CHAIRMAN

The CHAIRMAN. The Committee will come to order.

The great American inventor, Charles Kettering, once said: "We should all be concerned about the future because we will have to spend the rest of our lives there."

I, myself, would take that notion one step further: the future is where our children and grandchildren will spend their lives.

These are critical times for America and for the planet Earth—critical because the course we set here in Washington and the policies we pursue will have a profound impact on the Americans of tomorrow, their standard of living, and the quality of their lives.

The Twenty-first Century is only a little more than ten years away; yet the questions persist. Will Americans be working to secure their own future? Or will they be working merely to repay the mountain of debt we created during our years of profligacy?

Will they enjoy boundless economic opportunities in a nation that outpaces the rest of the world in the global economic competition? Or will their America be one of terminal economic degradation and decline?

Perhaps the most important reason we are here today is the question of environmental quality. It is frightening to think that our descendants might have to struggle for survival in a world lacking refuge from polluted air, fouled water, perennial drought, and dangerous solar radiation. Yet, in recent years, there is increasing evidence that the advancement of civilization is having some profound negative effects on our climate and our world.

We do not yet fully understand the effects of pouring carbon dioxide and other chemicals into our atmosphere, or destroying huge areas of forest. But scientists believe that, like the canary in the coal mine, our planet is now sending us warning signals that our planet's ability to sustain human life may face a long-term threat.

Hotter weather, severe droughts in the United States and in Africa, the Antarctic ozone hole and worldwide thinning of the ozone layer all serve to underscore the need for a national and international strategy to protect the fragile ecology of our planet, this "spaceship Earth."

Will Earth be uninhabitable someday if we ignore these signals? Maybe not. But the point is we do not know for sure.

In 1790, Edmund Burke defined the relationship between government and society as "a partnership not only between those who are living, but between those who are living, those who are dead, and those who are to be born." If we are to maintain our fiduciary relationship with generations to come, then we cannot fail in our responsibility to protect our environment from permanent, irreversible damage.

Clearly, our first priority must be to understand these changes—more precisely, to develop the scientific understanding needed to make rational policy decisions.

this is not a trivial undertaking. The scientific questions are fundamental and difficult because they require us to understand the Earth as a system. We must learn how the atmosphere, oceans, land, plants, and animals all interact; how, for example, destroying rain forests affects carbon dioxide in the atmosphere and how that change in turn affects world temperatures.

We now know that these interrelationships are far more complex than we once thought.

But, despite the ominous information we now have, there is a tremendous cause for optimism and reason to believe in the ability of man to find solutions to complex environmental questions. Scientists are now at the point where they can begin productive and valuable research into global environmental changes. An extraordinary effort has begun, involving scientists from many different backgrounds and using the most advanced satellites, instruments, and computer technology. Government and university researchers, working with their colleagues overseas, have begun to formulate sound plans to perform the necessary research and answer these critical questions. The issue now is how best to organize those efforts.

Our Federal research agencies have begun to respond. NOAA, NASA, and the National Science Foundation each have developed global change initiatives.

In NOAA, for example, the 1989 budget request contains an initiative for a climate and global change program. The program builds on ongoing NOAA responsibilities to monitor the oceans and atmosphere, manage environmental information, and improve climate prediction. The goal of the initiative is to provide reliable, long-term predictions of global climate change.

At the same time, NASA is working to put together the first phase of an international earth observation capability on the space station polar platform. This Earth observation system, now being developed cooperatively with the Europeans, Canada, and Japan, will enable scientists to more accurately monitor our lands, our seas, and our atmosphere. I understand that similar initiatives are underway at the National Science Foundation.

Equally important, these research agencies have begun to coordinate their efforts, so that we get one overall research program, rather than many small, fragmented ones. A Committee on Earth Sciences has been formed under the government's principal interagency science group, the Federal Coordinating Council on Science, Engineering, and Technology.

Federal advisory committees and the National Academies of Sciences and Engineering have provided very valuable assistance.

So, what is the Congress' role?

In my view, we should be lending our unmitigated support to this emerging research effort and we should be working to strengthen it, as well.

Last week, I, with my distinguished colleague, the Senator from Tennessee, who is sitting next to me—who has been a leader, incidentally, over the years in this particular endeavor—introduced S. 2614, the Global Change research Act, which would mandate a ten year Federal Government plan to study the phenomenon of global change. Many of our colleagues have cosponsored the bill—it is bipartisan—our Ranking Member, Senator Danforth, and others.

It is my attempt to formalize the current interagency research effort, to require sound planning, and to provide good budgetary information and coordination.

My hope is that a long-term coordinated research effort will one day give Congress the information it needs to take corrective action and avert a future global disaster.

This morning's hearing, then, has three purposes: to hear from the distinguished scientists about the dimensions of this global problem; to hear from the Executive Branch about its current plans; and to discuss the approach taken by my legislation.

The problem that we face is potentially enormous. Global warming alone could radically change world climate and world agriculture. Ozone depletion could cause tens of thousands of new cases of skin cancer. No one should underestimate the seriousness of our situation.

But if the challenge is enormous, the skill and tools of our scientists have never been better. Good answers to the pressing questions we face will not come easily, and probably not cheaply.

We need a determined and coordinated research effort both here in the United States and with other nations to get the facts about the exact causes and consequences of global environmental change. For our children's sake, now is the time to start.

We start our hearing this morning with testimony from the eminent scientist and policy expert, Dr. Robert White, formerly Administrator of the National Oceanic and Atmospheric Administration.

Before I call on Dr. White, who is now serving as President of our National Academy of Engineering, I want to yield to our distinguished colleague, Senator Gore.

OPENING STATEMENT BY SENATOR GORE

Senator GORE. Mr. Chairman, thank you very much for your kind words. Let me join you in welcoming our witnesses.

I would like to begin by applauding your leadership.

I have been pleased to join you in introducing S. 2614, the National Global Change Research Act of 1988. This Committee will have the primary task of organizing our nation's response to the greenhouse effect and to the depletion of the ozone layer.

Mr. Chairman, the current drought and scorching temperatures have seized the nation's attention. For many Americans just walking out the door in the morning is a daily reminder. Farmers from New Mexico to Pennsylvania and from Idaho to South Carolina are running out of time. Each week, more states are affected. A drought emergency now exists in more than 40 percent of the nation's counties. The Secretary of Agriculture has called it a "catastrophic thing" that will cause devastating damage."

But the current crisis is also a stern warning about the future. A disaster, by definition, is a sudden and unforeseen calamity—and unfortunately the current weather pattern is neither sudden nor unforeseen.

As I read the news reports and see first hand the tragedy the drought has brought to my own state, Tennessee, and to the country as a whole, I can't help thinking back seven years to the first hearing I chaired to examine global climate change caused by the greenhouse effect. At that hearing, Dr. James Hansen of NASA, Professor George Kukla of Columbia University, and others predicted climate changes identical to those that we are now experiencing.

I was quite alarmed by the information they presented, and it has been a top priority for me ever since.

I think back to the hearing that took place in this Committee just one year ago, July 16, 1987, in which it was said at some point Americans will wake up and say the current weather conditions have some connection to these longer-term trends.

We have seen that take place. We have seen people watch the news broadcasts and read about the greenhouse effect and put two and two together, and come to the conclusion that it is time for this nation to act.

The information given us by the scientists is, of course, alarming. The greenhouse effect sounds to some like the plot of a bad science fiction novel, and people are reluctant to believe it. But what started on the fringes of science is now in the mainstream, and there is no significant disagreement among atmospheric scientists the world over that the greenhouse effect is taking place and that we must respond to it.

The 1980's had already accounted for the four warmest years in the history of global measurements. 1988 not only seems headed to become the fifth, but threatens to suceed 1987 as the warmest year on record.

Yet while the greenhouse effect became the subject of a great many scientific meetings, and took its place as part of the lexicon of governmental worries, we have not taken specific steps to change the predicted course. Carbon dioxide emissions increase, as do CFCs, methane, nitrous oxide, and other greenhouse gases, while worldwide deforestation continues. Very little has been done to bring the impressive resources of the government scientific research agencies to bear on the problem.

Well, this long, hot summer the nation seems ready to wake up to the grave seriousness of the problem.

Stories about the greenhouse effect are no longer found only in scientific journals, but on the front page of newspapers across the country.

This unprecedented attention to the greenhouse effect presents a crucial opportunity. We should use it to put in place the policies necessary to prevent the tragic results of global warming.

A strong research program must be the foundation of our response. And as the cornerstone of that foundation I was pleased to join you, Mr. Chairman, in introducing S.2614, a bill establishing the National Global Change Research Act of 1988.

This bill, the subject of today's hearing, spells out a comprehensive, careful approach for studying earth sciences. It emphasizes an integrated view of the interactions of the lithosphere, the physical climate system, and the biosphere, and represents a departure from the traditional discipline-by-discipline approach.

If we are going to understand the full effect of our actions on the global environment, we must begin by viewing the earth as a dynamic system of interacting variables. It is not enough to study the oceans, the atmosphere, and the solid earth separately. We need to understand how they affect each other.

For too long we have allowed our nation's science policy to drift. As we reach for the stars, we must not forget the enormous amount we still don't understand about the earth.

Today's hearing is an opportunity to explore setting a new course—to recognize, for example, that in addition to manned space flight and the military use of space, space science is a critical third mission of our space program.

We are living through a period of unprecedented change, unprecedented population growth, and unprecedented stress on our environment. Space science, through the use of space-borne instruments and the study of other planets, will be an invaluable tool for earth scientists to accurately model environmental change.

Mr. Chairman, today's hearing is also an opportunity to put the Administration on notice. The greenhouse effect will not be solved by unilateral action, but will require the cooperation of all nations. The United States should be at the forefront of leadership on this issue. Yet two weeks ago in Toronto, during the World Conference on the Changing Atmosphere, the U.S. delegation sat back and passively watched. Fortunately, Canada and Norway led efforts that produced a conference statement calling on the most developed nations to reduce

carbon dioxide emissions 20 percent by 2005. Prime Minister Bruntland of Norway pledged to level off. energy use in her nation by the year 2000.

These are issues that will require bold leadership. We haven't had that from this Administration. This is just another in a long list of issues they would solve by crossing their fingers and wishing it will go away.

Today's hearing is another important step in establishing a record in support of action, so that we can act with the urgency this issue demands. I look forward to hearing from this morning's witnesses, and again, congratulate you, Mr. Chairman, for your work on S. 2614 and for calling this hearing.

Thank you.

The CHAIRMAN. Thank you very much, Senator Gore.

Senator Kassebaum is very interested in this, but she has to introduce a witness at another hearing, a typical conflict that we have.

Senator Gore's statement brings right into focus what we have heard and not heard financially. This points up the real need for coordination and the concentration of the effort itself, because financially—and I am going to put this chart into the record along with the bill—we have quite an endeavor going on and quite a talent arrayed.

ESTIMATED BUDGET SUMMARY OF GEDERAL GLOBAL CHANGE PROGRAMS

[In millions]

Agency	Programs	FY 88 actual	FY 89 request
NASA	Earth science research missions from space, satellite development	390	452
NSF	Basicv earth, ocean, atmospheric and polar research	*305	*336
DOD	U.S. Navy research on meteorology and oceanography	87	88
NOAA	Satellite and ocean observations, data management, modeling and prediction, research.	**35	*49
USDA	Climate impact assessment including weather, climate, state research services	22	22
DOE	Environmental program on carbon dioxide and other greenhouse gases	14	16
DOI	Climate change program research on sea level rise	13	14
EPA	Global climate change stratospheric ozone research	6	12

*Includes the Global Geosciences program with funds of $35 Million in FY 88 and a request of $47 million in FY 89.

**Does not include general environmental satellite procurement and operating costs.

In NASA alone, satellite development for their Earth science research missions from space, will cost about $390 million this year.

In the National Science Foundation this fiscal year, the budget for basic Earth, ocean, atmospheric, and polar research will be $305 million.

Within the Department of Defense, U.S. Navy research on meteorology and oceanography is $87 million.

In NOAA, the satellite and ocean observations data management modeling and prediction research will be $35 million. Ant that figure does not include the procuring or operating environmental satellites or data center operations.

The budget for Department of Agriculture climate impact assessments, including weather, climate, and state research services, is $22 million.

The Department of Energy's environmental program on carbon dioxide and other greenhouse gases is $14 million.

The Department of Interior's climate change program and research on sea level rise is $13 million.

At the Environmental Protection Administration, research on global climate change and stratospheric ozone is funded at $6 million.

All of those amounts are due for increases under the present 1989 approved budget.

So, you get a good feel of over $800 million or close to a billion bucks being expended. And yet, we, as a body politic, are not that well informed and don't know exactly where we are headed. All we are hearing now are cover stories about the ozone effect. Of course, that is only one part of it.

[The bill follows:]

II

100TH CONGRESS
2D SESSION

S. 2614

To amend the National Science and Technology Policy, Organization, and Priorities Act of 1976 in order to provide for improved coordination of national scientific research efforts and to provide for a national plan to improve scientific understanding of the Earth system and the effect of changes in that system on climate and human well-being.

IN THE SENATE OF THE UNITED STATES

JULY 7, 1988

Mr. HOLLINGS (for himself, Mr. KERRY, Mr. RIEGLE, Mr. ROCKEFELLER, Mr. GORE, Mr. DANFORTH, and Mr. PRESSLER) introduced the following bill; which was read twice and referred to the Committee on Commerce, Science, and Transportation

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A BILL

To amend the National Science and Technology Policy, Organization, and Priorities Act of 1976 in order to provide for improved coordination of national scientific research efforts and to provide for a national plan to improve scientific understanding of the Earth system and the effect of changes in that system on climate and human well-being.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "National Science and Technology Policy Amendments of 1988".

SEC. 2. Section 102(a)(6) of the National Science and Technology Policy, Organization, and Priorities Act of 1976 (42 U.S.C. 6602(a)(6)) is amended to read as follows:

"(6) The development and coordination of long-range, interagency research plans to support policy decisions regarding identified national and international concerns, and for which a sustained and coordinated commitment to improving scientific understanding will be required.".

SEC. 3. Section 401 of the National Science and Technology Policy, Organization, and Priorities Act of 1976 (42 U.S.C. 6651) is amended—

(1) by redesignating subsections (f), (g), and (h) as subsections (g), (h), and (i), respectively;

(2) by inserting immediately after subsection (e) the following:

"(f) The Council may be assigned responsibility for developing long-range and coordinated plans for scientific and technical research which involve the participation of more than two Federal agencies. Such plans shall—

"(1) identify research approaches and priorities which most effectively advance scientific understanding and provide a basis for policy decisions;

"(2) provide for effective cooperation and coordination of research among Federal agencies; and

"(3) encourage domestic and, as appropriate, international cooperation among government, industry, and university scientists."; and

(3) in subsection (i), as so redesignated, by inserting "developing interagency plans," immediately after "purpose of".

SEC. 4. The National Science and Technology Policy, Organization, and Priorities Act of 1976 (42 U.S.C. 6601 et seq.) is amended by adding at the end thereof the following new title:

"TITLE VI—NATIONAL GLOBAL CHANGE RESEARCH PLAN

"SHORT TITLE

"SEC. 601. This title may be cited as the 'National Global Change Research Act of 1988'.

"FINDINGS AND PURPOSE

"SEC. 602. (a) Congress finds and declares the following:

"(1) Industrial, agricultural, and other human activities, coupled with an expanding world population, are contributing to processes of global change that may significantly alter our habitat within a few human generations.

"(2) Such human-induced changes may lead to significant global warming and the depletion of stratospheric ozone, and thus have the potential to alter

world climate patterns, increase global sea levels, and reduce the ability of the atmosphere to screen out harmful ultraviolet radiation. Over the next century, the consequences could seriously and adversely affect world agricultural and marine production, coastal habitability, regional economic well-being, human health, and biological diversity;

"(3) Development of effective policies to mitigate and cope with human-induced global changes will rely on greatly improved scientific understanding of global environmental processes and on our ability to distinguish between the effects of human activities on one hand and the results of natural change on the other.

"(4) New developments in interdisciplinary Earth sciences, global observing systems, and computing technology make possible significant advances in the scientific understanding and prediction of these global changes and their effects.

"(5) Efforts are ongoing in several Federal agencies which could contribute to a well-defined and coordinated national program of research, monitoring, assessment, and prediction.

"(6) The United States, as a world leader in Earth system science, should continue to provide leadership

in developing and implementing an international global change research program.

"(b) It is the purpose of Congress in this title to provide for a national global change research plan which when implemented will assist the Nation and the world to understand, assess, and respond to human-induced and natural processes of global change.

"NATIONAL GLOBAL CHANGE RESEARCH PLAN

"SEC. 603. (a)(1) The President, through the Council, shall develop a National Global Change Research Plan (hereafter in this title referred to as the 'Plan') in accordance with section 401(f) of this Act and the provisions, findings, and purpose of this title. Consistent with the responsibilities set forth under subsection (d) of this section, the Plan shall contain recommendations for a ten-year national research effort, to be submitted to Congress within one year after the date of enactment of this title and to be revised at least once every three years thereafter.

"(2) The Plan shall—

"(A) establish the goals and priorities for Federal global change research for the ten-year period beginning in the year the Plan (or revised Plan) is submitted;

"(B) set forth the role of each Federal agency and department in implementing the Plan;

"(C) describe the levels of Federal funding and specific activities, including research activities, data collection and analysis requirements, participation in international research efforts, and information management, required to achieve such goals and priorities; and

"(D) consider and utilize, as appropriate, reports and studies conducted by Federal agencies and departments, the National Research Council, or other entities.

"(3) The Plan shall address, where appropriate, the relevant programs and activities of the following Federal agencies and departments:

"(A) the Department of Commerce, particularly the National Oceanic and Atmospheric Administration;

"(B) the National Science Foundation;

"(C) the National Aeronautics and Space Administration;

"(D) the Department of Interior, particularly the United States Geological Survey;

"(E) the Department of Energy;

"(F) the Department of Agriculture;

"(G) the Environmental Protection Agency;

"(H) the Department of Defense, particularly the Department of the Navy; and

"(I) such other research agencies and departments as the President or the Chairman of the Council considers appropriate.

"(b) The Council shall—

"(1) serve as lead entity responsible for oversight of the implementation of the Plan;

"(2) coordinate the global change research activities of Federal agencies and departments and report at least annually to the President, through the Chairman of the Council, on any recommended changes in agency or departmental roles that are needed to better implement the Plan;

"(3) following the President's submission to Congress of the annual budget estimate, review each agency budget estimate in the context of the Plan and make the results of that review available to each agency and to the appropriate elements of the Executive Office of the President, particularly the Office of Management and Budget;

"(4) work with the National Research Council and with academic, State, and other groups conducting research and assessments of global changes and their effects;

"(5) coordinate Federal interagency participation in international activities related to global change research and assessment; and

"(6) consult with actual and potential users of such research and assessments.

"(c) The Plan shall provide for, but not be limited to, the following research elements:

"(1) Global measurements, establishing worldwide observations necessary to understand the physical, chemical, and biological processes responsible for changes in the Earth system on all timescales.

"(2) Documentation of global change, including the development of mechanisms for recording changes that will actually occur in the Earth system over the coming decades.

"(3) Studies of earlier changes in the Earth system, using evidence from the geological and fossil record.

"(4) Predictions, using quantitive models of the Earth system to identify and simulate global trends.

"(5) Development of an information base, the assembly of the information essential for effective decisionmaking to respond to the consequences of global change.

"(d)(1) The Plan shall take into consideration, but not be limited to, the following existing agency missions and responsibilities:

"(A) The National Science Foundation shall continue to be responsible for basic research in all areas of Earth, atmospheric, and ocean science, including the relevant biological sciences. Such basic research may include ground-based measurements for regional and global studies; polar studies; large-scale field programs; interpretation and use of space-based data; theoretical and laboratory studies; research facilities support; and develop.ent of numerical models, information and communication systems, and data bases.

"(B) The National Aeronautics and Space Administration shall have primary responsibility for Earth science research missions from space, including those of broad scientific scope, to study the Earth as an integrated whole. Associated efforts may include related ground studies; remote-sensing and advanced instrument development; and improvement of techniques for the transmission, processing, archiving, retrieval, and use of data and related models; and other research activities.

"(C) The National Oceanic and Atmospheric Administration shall continue to be responsible for oper-

ational environmental satellite programs and research programs on ocean and atmospheric processes. Additional responsibilities shall include climate diagnostics and prediction; development of predictive models and techniques for detecting natural and human-made changes; acquisition, maintenance, and distribution of long-term data bases; calibration and validation of environmental observations; processing and archiving of space-based data; and development and support of ground-based oceanic and atmospheric monitoring systems.

"(D) The United States Geological Survey shall have primary responsibility for geological studies and mapping. Additional areas of responsibility shall include paleoclimate, hydrologic cycles, geographical information systems, and management of land remote-sensing data, including acquisition, maintenance, and distribution of long-term data bases for these areas.

"(2) The Plan shall reflect the need for collaboration among agencies with respect to—

"(A) the establishment and development of an information system for Earth system science; and

"(B) basic research into the development of new conceptual and numerical models of the Earth system.

"(e) The Chairman of the Council and the Secretary of State shall cooperate in—

"(1) providing representation at international governmental meetings and conferences on global change in which the United States participates; and

"(2) coordinating the Federal activities of the United States with the global change research and assessment programs of other nations and international agencies and organizations, including the World Meteorological Organization and the United Nations Environmental Program.

"(f) Each Federal agency and department involved in global change research shall, as part of its annual request for appropriations to the Office of Management and Budget, submit a report identifying each element of its proposed global change activities, which—

"(1) specifies whether each such element (A) contributes primarily to the implementation of the Plan or (B) contributes primarily to the achievement of other objectives but aids Plan implementation in important ways; and

"(2) states the portion of its request for appropriations that is allocated to each such element.

The Office of Management and Budget shall review each such report in light of the goals, priorities, and agency re-

sponsibilities set forth in the Plan, and shall include, in the President's annual budget estimate, a statement of the portion of each agency or department's annual budget estimate that is allocated to each element of such agency or department's global change activities. The Office of Management and Budget shall ensure that a copy of the President's annual budget estimate is transmitted to the Chairman of the Council at the same time as such budget estimate is submitted to Congress.

"RELATION TO OTHER LAWS

"Sec. 605. (a) The President, the Chairman of the Council, and the Secretary of Commerce shall ensure that the research elements of the National Climate Program, established by the National Climate Program Act (15 U.S.C. 2901 et seq.), are made an integral component of national global change research efforts.

"(b) The President, the Chairman of the Council, and the heads of the agencies represented on the Council shall ensure that the research findings of the Council and of Federal agencies and departments are available to the Environmental Protection Agency for use in the formulation of a coordinated national policy on global climate change pursuant to section 1103 of the Global Climate Protection Act of 1987 (15 U.S.C. 2901, note).

"ANNUAL REPORT

"Sec. 606. (a) The Chairman of the Council shall prepare and sumbit to the President and Congress, not later than January 31 of each year, an annual report on the activities conducted pursuant to this title during the preceding fiscal year, including—

"(1) a summary of the achievements of Federal global change research efforts during that preceding fiscal year;

"(2) an analysis of the progress made toward achieving the goals and objectives of the Plan;

"(3) a copy or summary of the Plan and any changes made in such Plan;

"(4) a summary of agency budgets for global change activities for that preceding fiscal year; and

"(5) any recommendations regarding additional action or legislation which may be required to assist in achieving the purposes of this title.

"(b) The annual report required under section 7 of the National Climate Program Act (15 U.S.C. 2906) may be incorporated into the annual report required under subsection (a) of this section.".

○

The CHAIRMAN. I am particularly pleased, Dr. White, to have you with us again. While you are coming forward, I will introduce you as head of the National Academy of Engineering.

Dr. White helped organize us back in 1970, when we instituted the National Oceans and Atmospheric Administration.

I had had three years of hearings in this particular Committee in what was then the Subcommittee on Oceans and Atmosphere. Using Dr. Julius Stratton's report, the Stratton Commission Report, we went over to my friend, John Mitchell, the Attorney General, whom I knew as a lawyer. I went to him to get around John Ehrlichman, who was a land use lawyer, and who was going to stop anything going to President Nixon relative to any kind of coastal zone management, any kind of oceans and atmospheric coordination.

We went around and we got Jack Mitchell to go to President Nixon. Then, in July, we received Reorganization Plan Number Four.

Dr. White is the one who gave us the character, the leadership and the success of that particular agency—its language.

Since your leaving, Dr. White, every Secretary of Commerce comes into town and says, "Oh heavens, I came here for big business and foreign trade, and I look around and find that 60 to 70 percent of my budget, maybe more, is wrapped up in this weather crowd." And who can predict the weather? As Will Rogers says, "Just sit around and it will change," so why spend all that effort?

As a result, it has been minimized, debunked and cut fiscally, and it has been an uphill struggle to maintain it.

In hearing you this morning, let me say this to all the witnesses. When we have our panels, we will have to limit the Senators and the panels to five minutes each because we have a roll call coming up at 10:00 o'clock. You will have a good ten minutes, Dr. White. We will give you all equal time, but we will have that roll call soon, and then we have another important meeting at 11:45 that all of us are required to attend.

So let us hear from you. You are welcome here this morning.

STATEMENT OF ROBERT M. WHITE, PRESIDENT, NATIONAL ACADEMY OF ENGINEERING

Dr. WHITE. Thank you, Mr. Chairman and Senator Gore. It is good to be back once again, and I am especially pleased to appear before you to discuss global change issues.

The time is propitious, as Senator Gore points out. It is hard to pick up a newspaper without having problems of global climate and stratospheric ozone changes highlighted.

We have governmental leaders also commenting on the consequences of climate warming and the decrease in stratospheric ozone.

President Reagan and General Secretary Gorbachev signaled the intent of the United States and the Soviet Union to collaborate in addressing the problem at the recent Washington summit meeting.

Governor Michael Dukakis in Colorado last week indicated his interest in a United Nations summit on the greenhouse problem.

The recent international conference on global change held in Toronto several weeks ago addressed similar problems, and, as Senator Gore has pointed out, the Prime Minister of Norway gave clear voice to growing concerns.

In the Federal Republic of Germany, under the auspices of the president of that country, an International Conference on Climate and Development will take place in Hamburg in November, and they are planning to produce something they call a "Hamburg Manifesto."

The Montreal protocol to restrict the production of CFCs was a milestone in addressing the ozone problem, and, as if to punctuate the importance of the issues, the present devastating drought in the United States has demonstrated once again that society is at the mercy of atmospheric forces. The drumbeat has now become incessant.

There is consensus, as has been pointed out by yourself, Mr. Chairman, in the scientific community internationally, that humanity faces a potentially serious problem. Climatic change is today the overarching global environmental problem. It is caused by the most basic actions of humanity—the use of energy, agriculture, land use, industrial practices.

And, although there is much that we do not yet know or understand, it is also true that much is known of our climatic and stratospheric ozone fluctuations as a result of the investment by our government and other governments in atmospheric and oceanic research.

What are the facts?

From observations during the past 35 years at observatories in many parts of the world, including Mauna Loa, in Hawaii, we have irrefutable evidence of the inexorable and systematic increase in the amount of carbon dioxide in the atmosphere.

The only plausible source for such a large increase is the burning of fossil fuels—coal, oil, and gas.

We also have good records of the increase of many trace gases, such as methane, nitrous oxide, and CFCs. These gases, known as greenhouse gases, affect the atmospheric transmission of energy radiated by both the sun and the Earth. They act to trap energy in the lower part of the atmosphere, thus warming the layers of the atmosphere near the surface of the Earth.

Observations of stratospheric ozone from ground and satellite based instruments have shown decreases of varying intensity in ozone content over the past two decades.

Now, what are the consequences for climate change of these observations?

Scientists simulate the atmosphere and the oceans with mathematical models. Computer calculations are then able to describe the consequences. These calculations predict an increase in the average global temperature over the surface of the Earth of about 1.5 to 4.5 degrees Centigrade. This temperature increase would accompany a doubling of the carbon dioxide content in the atmosphere.

The simulations also tell us that the temperature increases in the polar regions will be much larger than those in the mid-latitude or tropical regions. There is a high level of confidence in the scientific community in these predictions.

The predictions also provide information about the distribution of precipitation.

Other projections and conclusions about the effect of these changes on agriculture, water resources, and sea level represent a third tier of conclusions, and they are less certain.

What are the nature of the uncertainties that we face?

Principal among them is the pace at which carbon dioxide and other trace gases will be emitted to and remain in the atmosphere in the years ahead. This will depend largely on the rate of growth of the types and amount of energy use.

We are uncertain about this rate of growth, so scientists turn to what they call "scenarios." They ask what if the rate of increase of energy use were, for example, 1 percent or 3 percent. These scenarios indicate that we could see a doubling of the atmospheric carbon dioxide content around the middle of the next century. The doubling has no significance other than to provide a benchmark.

Other major uncertainties stem from the inability to incorporate certain atmospheric and oceanic physical processes with great fidelity in the mathematical models. As a result, the simulations become very uncertain when local and regional changes in temperature are calculated. The simulations also do not treat moisture, cloudiness, and rainfall with great accuracy. The result is that precipitation calculations are less certain than temperature predictions.

Is there observational evidence that the climate is changing? Yes, there is.

We have evidence that is consistent with the hypothesis of a warming climate. The evidence, however, cannot be regarded, as Senator Gore points out, as proof.

There are two main types of observational evidence. Over the past century, there is observational confirmation of a warming of the climate. Surface temperatures have risen about 0.6 degrees Centigrade, and observations also indicate that there has been a small rise in the height of sea level.

Could these climate changes be natural fluctuations?

Climate is known to fluctuate naturally over all time scales and in all parts of the world. Droughts and floods have been traditional scourges of humanity for thousands of years. Our observations and experience in the United States and throughout the world record that climate warms and cools, droughts occur and disappear, and periods of flooding are succeeded by periods of aridity.

Separating the natural from the man-made changes presents scientists and policy-makers with a major dilemma, one of the points made in the draft legislation.

At the present time, we can say only that the evidence does not controvert the theory of climatic change.

Can we do anything to address the potential threat?

The course we must follow is one of prudence, not one of panic. We must set as policy objectives those courses of action that enable us to address the threat, but not those courses of action that will reduce our op-

tions for the future or restrict those future actions in the light of increased knowledge of man's impact on climatic change.

There are policy decisions that can help and make good sense. First, as both national and international policy, we must support those activities that will reduce the uncertainties in our knowledge of climate change.

Second, we need to adopt policies that can slow down the rate of increase of carbon dioxide and trace gases.

Third, we can examine actions that will position us to adapt to changes in climate.

You have asked that I focus on the need for research to increase our knowledge of climate change. I could not appear before you, however, without commenting on energy policy options since the burning of fossil fuels is at the root of the problem and since society needs access to cheap and reliable energy. This dilemma will be at the center of the policy debate only now beginning.

Some energy policies that we must follow are self-evident. Any reduction in the use of fossil fuels will slow down the rate of increase of the offending gases. Increased energy efficiency in everything we do must become the foundation of national and international policy.

As a matter of policy, we must encourage the use of those fossil fuels that contribute the least amount of carbon dioxide to the atmosphere.

Among fossil fuels, natural gas is clearly the fuel of choice, and our policies must provide incentives for the increased use of natural gas in place of coal or oil

It would also be wise to seek international means of slowing the destruction of natural forests, especially in the tropics, and to reverse the process, thereby increasing the biospheric storage of carbon.

These policy directions will slow down the rate of increase, but not eliminate it. Ultimately, we must move to the use of nonfossil fuels. Hydro and solar power and other alternative energy sources can help to meet our energy needs, but will not suffice.

If the greenhouse effect proves as serious as many believe, we must reexamine our policies on nuclear power. We should consider revisiting the nuclear power question in a fresh way. We need to invest in research and development on nuclear energy technologies that are inherently safe and acceptable to the public.

Let me now focus on research needs.

Our government has invested heavily in atmospheric and oceanic research in the past years, and this investment is now paying off in our understanding of climate changes. More research, however, needs to be done, and done in collaboration with other nations as an international endeavor.

First, we need to reduce the uncertainties that result from our present crude simulations of atmospheric and oceanic systems. I mentioned that there are certain physical weaknesses in the models, such as the inability to simulate cloud formation processes well. We need more information about these processes and how to introduce them into mathematical models. We also need access to greater computational

capabilities. That means investments in computers and computational facilities that will enable us to use more powerful mathematical models.

Second, a most important area for significant investment in research and development is monitoring atmospheric and oceanic conditions. I would regard this as the most urgent task before us.

We need to develop both the techniques for monitoring and the international agreements that will allow us to place instrumentation where it is needed. Fortunately, we can have access to space based monitoring systems of the United States and other nations if we make the necessary investments. The purpose of these monitoring systems will be severalfold. We need to be able to detect the evidences of climatic change, and this can be done only through a much improved monitoring system. We also need better estimates of the emissions from industrial and agricultural processes of concern, so that we can be more precise in our projections of emissions that bring about climatic changes.

Because the climatic effects of greatest concern will be those upon the biosphere and upon water resources, we will want especially to develop systems for monitoring these conditions.

The effects of climatic change on all aspects of society need to be further probed. We need to know better the economic consequences of climatic changes in various regions. The ramifications are extensive and complex, and the present drought demonstrates how pervasive the societal effects of climatic change can be.

Finally, let me comment on the institutional and management problems inherent in prosecuting a program like global and/or climate change.

We have serious definitional problems in specifying the composition of a program called "Global Change," and a program called "Climate Change." We run the danger of stumbling over definitions and separate agency authorities.

Clearly, global change involves many aspects of climate change. The fact is that the problems are complex and span the interests and capabilities of many agencies, and unless we clarify the areas of responsibility, we are going to continue to move slowly.

Your legislation, S. 2614, presents the issue well. The solution, however, I think is less clear.

Mr. Chairman, my testimony is intended to be brief and not comprehensive, to highlight the main points of our knowledge and to urge the need for further research into climatic processes. Such research is needed to provide a basis for public policies, established in the light of knowledge, rather than emotion.

Thank you.

I would be glad to answer any questions.

The CHAIRMAN. Dr. White, how would you organize this? Suppose you were king for a day? What would you change now that is ongoing?

In other words, I am on the Budget Committee, too, and I am sitting down and spending, and I am listening to Senators. In fact, yesterday afternoon I was bemused because I heard two Senators on the floor say we weren't doing anything.

That reminded me of "Newsweek," do you know what I mean? All of a sudden, there was a problem.

We think government and the world begins when we get the magazine on the weekend, or whatever.

I am looking at the budgets here and I am spending three quarters of a billion dollars or upwards. I have a lot of talent and I have several on-going endeavors throughout the government.

Now, you and I have been into this kind of problem before. Are there any areas that are particularly neglected? Are there any particular changes needed? Is there any particular organization we should use? This bill, is it lousy? Should we throw it away? Is the approach wrong?

You have talked like a scientist. Now talk like a politician. How do we organize this?

Dr. WHITE. As I said, I think the bill catches the issue well.

The CHAIRMAN. Do you think so?

Dr. WHITE. It calls for a national plan. I think that is the first step. We have to know what it is we are planning to do and how much it is going to cost.

The second essential thing—and I think your bill deals with that also—is how you have a unified budget that you can look at, that you can understand, which heads towards the goals that you would set in this plan.

The budget process now is not unified, and it has to be. The management process has to be more unified.

So, as I say, I think you have it well in the draft legislation. There is no question you know what the issues are.

The CHAIRMAN. Well, I thank you.

Let me yield, on that roll call vote, to Senator Gore, our expert in this.

Senator GORE. Now I don't know if I want that designation.

I appreciated your statement. I thought it was a very fine statement. You talked about how one of the classic problems here is discerning a long-term trend by pulling it out of what they call the "noise level" in the data.

Statisticians have techniques for massaging numbers, identifying changes as significant, and distinguishing them from normal fluctuations.

Am I correct in saying that the year to year increase from last year to this is so far four times larger than the standard fluctuation in the noise level?

Dr. WHITE. The increase in temperature?

Senator GORE. Yes.

Dr. WHITE. I don't know whether it is four times. Obviously we have a significant increase.

Senator GORE. Four times larger than the——

Dr. WHITE. Than the normal annual fluctuation.

Senator GORE. —than the normal fluctuation, right.

Dr. WHITE. It is large, but I don't know whether it is four times.

The problem that you face, Senator, is that natural climate fluctuations occur over all time scales.

Senator GORE. Right.

Dr. WHITE. To identify a particular fluctuation as being due to a specific cause, in this case increase in carbon dioxide, is a tough, tough thing to pull out.

I think the most you can say is that it is consistent with what we would expect from the greenhouse effect, and that if it is consistent, until proven inconsistent, you ought to take the prudent course of action.

Senator GORE. Well, in fact, the consensus in the community, in the scientific community, is really stronger than that, isn't it, on the point that the warming is taking place and that the effect is here and now?

Isn't there a pretty strong consensus in support of that proposition?

Dr. WHITE. There is an effect here and now. That is clear. It is incontrovertible that the surface temperatures have increased.

Tying it to the specific, increase in the carbon dioxide, is where the difficulty occurs, and you get a division of opinion on that in the scientific community.

Senator GORE. Well, I don't want to review the basics of the issue with you because we are focusing on a sensible research program, on how to better coordinate the money that is already being spent, and on how to come up with a good plan.

It has always seemed somewhat ironic to me that we approach questions about the atmosphere of Venus and Mars in a more deliberate, scientific way than we have yet really used in looking at questions of profound and central importance to us, here on this planet.

Do you agree with many of us here that we can make effective use of space resources in the kind of coordinated program the Chairman has proposed? That we can pull together all this information and dramatically reduce the uncertainties in the global climate models and other areas of knowledge relevant to this problem?

Dr. WHITE. I think space resources, space vehicles, satellite technology, are indispensible to dealing with the problem.

Senator GORE. I will have some other questions for the record, Mr. Chairman. But with the vote on, I will cut this short.

The CHAIRMAN. I think Senator Gore has highlighted just exactly what this Committee is concerned with, with NASA and NOAA and the National Science Foundation, and the great surge now for a space mission to planet Mars.

We, here in this Committee, are also interested in planet Earth, a "mission to planet Earth," as Sally Ride recommended here not long ago.

Senator McCain, do you want to ask a few questions of Dr. White, before the bell, or come back? As you wish?

Senator MCCAIN. Mr. Chairman, I would just like to make a couple of comments, if I could, as briefly as possible.

The CHAIRMAN. Surely.

Senator MCCAIN. First, I would like to be added as a co-sponsor of this legislation because I think it is excellent and important.

The CHAIRMAN. Yes, sir.

Senator MCCAIN. Dr. White, you mentioned in your statement that we will have to, in your words, consider revisiting the nuclear power questions in a fresh way. That is a very diplomatic statement, but I think it is a crucial one.

Congressman Udall and I introduced a bill this morning calling for the DOE and the NRC to come up with a standardized design for a safe nuclear power plant. We are going to have to take that into consideration in our energy needs in the next decade, and perhaps we can look at what other countries are doing—the Swedes, the French, and the Japanese and practically every other Western industrialized nation—who have made nuclear power an acceptable method of energy generation with their populations. I think we can achieve it as well. And, the sooner we get about this, Mr. Chairman, the better off we are going to be.

It all has to do with confidence by the American people that we can build a reactor that is safe, and until we have a standardized design, that is not going to happen in my view.

I wonder if Dr. White agrees with that rather emotional assessment.

Dr. WHITE. If we are right about the greenhouse effect, we are going to have to move to non-fossil energy sources at some time. Fortunately, we have time to develop and make the investments necessary, to look at alternative energy sources, a prime one among them being, of course, nuclear energy.

We have two things to get over in order to do that. It has to be acceptable to the public, and we know what has happened as a result of nuclear power being unacceptable to the public. And it has to be inherently safe. The public has to understand that it takes no external devices, valves, controls in order to take care of any excursion in a nuclear reactor, that natural physical processes will take care of it untouched by human hands. That is what we mean by "inherently safe."

Senator MCCAIN. And do you think we can do both?

Dr. WHITE. I think it is worth a major investment in doing it. I think the potential for doing it is good.

Senator MCCAIN. Thank you, Mr. Chairman.

The CHAIRMAN. Very good.

The Committee will be at ease until we come back from the vote.

[Brief recess.]

The CHAIRMAN. Dr. White, thank you.

We will move now to the next panel due to our crunch of time. These are all important witnesses, and we hate to limit them. We will include their full statements in the record.

We have next a panel consisting of Dr. Francis Bretherton and Dr. Dallas Peck.

Dr. Bretherton is a Senior Scientist at the National Center for Atmospheric Research, and Dr. Peck is Director of our U.S. Geological Survey.

Then, following this panel, we will have another panel of four distinguished individuals.

Let's start with you, Dr. Bretherton. Thank you.

STATEMENT OF FRANCIS P. BRETHERTON, CHAIRMAN, NASA EARTH SYSTEM SCIENCES COMMITTEE, AND SENIOR SCIENTIST, ATMOSPHERIC ANALYSIS AND PREDICTION DIVISION, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Dr. BRETHERTON. Mr. Chairman, I would particularly like to welcome this opportunity to share with you some concerns. The details of these are, indeed, in my written statement, which I would like to place in the record.

I would like to start by paraphrasing some of the things that Dr. White was explaining, that the scientists indeed are concerned about.

Let's start by imagining this Committee meeting 50 years from now, in 2038, reviewing what is going on in the world.

The CHAIRMAN. And, of course, I will still be here.

Dr. BRETHERTON. Well, it might possibly be your successor.

Now, in the scenario I am about to present, I must emphasize the details are fantasy, but the underlying environmental changes are consistent with what you keep hearing the scientists believe.

I would also like to emphasize that the changes in this scenario are not all bad. I am not saying the sky is falling. I am saying there is a mix of some things that are good, or helpful, others that are clearly bad, and others that are probably of no consequence.

But we don't know enough to say which is which; and, in particular, I think we can say that all change is likely to be more stressful if we don't accurately perceive what is happening and if we don't understand what could be done either to adjust to it or ameliorate it.

But let me proceed now to the year 2038. Let's start in New York City, in August.

It is 95 degrees Fahrenheit outside, with 95 percent relative humidity. A day, the type of day, that is very familiar, but it got that way about July 4, and we must expect it to stay that way till after Labor Day, without a break, because every summer in New York is now hot and long.

On the other hand, one goes to Alaska and the place is booming. The fishing industry has tripled its catch in the last ten years because changes in the ocean currents are bringing new supplies of nutrients into the fishing areas.

In Washington and Oregon, the timber industry is booming. It is king again, with a plentiful supply of first-rate lumber for the whole world.

On the other hand, if we move to the mid-section of the country, to Nebraska, Kansas, Oklahoma and Texas, it is a desert. The dust bowl of the thirties is back, seemingly to stay.

The Ogalala Aquifer, the source of all the irrigation water, was mined dry 20 years ago. It is no more. And there is nothing for the people to do but to move.

Where are they going?

They are not going to California or to the South. They are going North, to Canada, because, under the influence of the greenhouse warming, the subarctic is finally being opened up to human settlement. With all its enormous natural resources, indeed it is not too much to speculate that at this time, the two most powerful nations in the world might be Canada and the Soviet Union.

In a different vein, let's imagine what the United Nations might be preoccupied with, and that would be how to deal with an international cartel which some 20 or 30 years before bought up all the remaining forests, tropical forests, in the Amazon, in Indonesia, Malaysia and in East Africa. It is now holding the world to ransom, simply extracting anything the market will bear.

And why? Because in that forest and only in those forests is the genetic material which is now absolutely essential for developing a new, fungus-resistant, strain of rice.

Now, as I said, the details of that are fanciful. But we do know that carbon dioxide and methane are going up and have been going up since the beginning of the Industrial Revolution. We do know that they are likely to warm the Earth as a whole, particularly in high latitudes, and we do know that the Earth, as a whole, is likely to be wetter. We don't know how fast this is likely to happen. It depends on how much carbon dioxide is put into the atmosphere and where it goes, into the oceans or if it stays into the atmosphere, and how much heat goes into the oceans.

We do not, in fact, know whether the interiors of continental regions are likely to be drier, as in my scenario, or perhaps even somewhat wetter. We do not know what is causing the rise of methane worldwide. It is clearly associated with human activities, in some way with agriculture. We have no real idea of the specific mechanisms in a quantitative way.

We do know that tropical forests are the richest environment there is in terms of species diversity, and we also know they are disappearing to development at an unprecedented rate. We do not know, however, what the effects of that loss of the priceless heritage from billions of years of evolution will be on our ability to produce food or on the emissions of trace gases into the atmosphere.

We do know that forests are natural ecosystems and often seem to show a remarkable resilience to stress, to change—for example, to acid precipitation raining on the forest; to slow climate changes; to infestation by insects. We know they seem very resilient to that. And then, all of a sudden, the whole forest dies back.

We do not know where that breakpoint is, and we must expect to be taken by surprise in that sort of way.

Senator GORE. May I interrupt for a point here?

The CHAIRMAN. Go ahead.

Senator GORE. The tropical rain forests are not resilient, are they—I mean, when they are cut down?

Dr. BRETHERTON. No. When they are cut down, they are gone.

Senator GORE. They are gone. Thank you.

Dr. BRETHERTON. But a natural ecosystem has certain margins within which it is resilient. We don't know where those margins are. We might just exceed them and then everything is gone.

But, in a broader vein, we do know that issues like ozone depletion, acid rain, desertification, economic development in Third World countries, these are agricultural policies that bring marginal land under cultivation. These are all very important regional issues.

We do know that we have to look at those in a global perspective to see the way they interact and how they interplay on each other. But we don't know how to do that.

So, how do we address these issues?

The specifics are being written down elsewhere in a number of reports that I am sure you have seen. We know that we are talking about a long-term program of basic research to gain understanding of how the entire system operates.

We need long-term global measurements, both satellite and in situ. We need the computer models to synthesize, diagnose, and predict what is happening. Above all, we need the information systems in place that retain the data that give access to this information, not only to scientists throughout the world, but also to their peoples and their governments.

But I would like to conclude with a brief discussion of two policy issues.

The first is that we all recognize the need to address fundamental environmental policy issues, like, for example, a new look at our nuclear strategy, that is, a strategy for nuclear power—I beg your pardon.

However, we also know that a sound basis of knowledge is all important in good policymaking, and the basic research program I am talking about has clearly got to be connected to the policy discussion, but kept somewhat separate from it, for three reasons.

The first is that the time scale for making significant advances in science is long—decades, in the case of what we are talking about. That program cannot be supported by a sequence of crash programs, all of them trying to address the issue of the moment.

The second reason is that we very much need to draw upon a broad spectrum of capability that is spread through many agencies—through the academic community, but particularly through agencies like the National Science Foundation, NOAA, NASA, the United States Geological Survey, the Department of Energy. They all have roles to play in this program.

They also have other responsibilities, and those other responsibilities support, or can support, rather than detract from, their ability to contribute to global change.

So we have to work within that matrix environment of existing responsibilities and graft on top of it a basic research program that is properly related to the policy discussions.

I believe S. 2614 is a major step forward in this direction.

The second issue I would like to address is the new NOAA.

When we are meeting 50 years from now, it is possible that you would say, Dr. Bretherton, that's a very fine story, but where is the evidence?

Right now, we don't really have very much evidence as scientists—some, but the real evidence of change, in terms of changing temperature, changing precipitation patterns, as Dr. White pointed out, is flimsy and controversial. We don't have that "smoking gun" of a long-term record that documents exactly what happened, and that has to be the cornerstone of our program.

And who is going to do it? Not NSF. That's not really the way they function. It is not NASA. They are an R&D agency. But the agency that has that central responsibility for long-term monitoring and measurement and the information systems that go with it, the agency that has that responsibility now, at least in the atmospheric and oceanic areas, is NOAA.

But, in order for NOAA to perform this role, it will have to change. It will have to mature, to the real dream, I think, of the founders of NOAA 20 years ago. It will have to rise above preoccupations with weather predictions and coastal zone management, and make sure that it really is a central agency for the long-term global issues of paramount interest to the peoples of this world.

That will require, first of all, outstanding leadership. Things do not change easily. It is not talking about business as usual.

Secondly, it will certainly need substantial resources. Finally, it will take time.

Now, we are not going to be able to do this simply by robbing Peter to pay Paul. It would be a mistake. In fact, I am sure it would be counterproductive to launch a global change program at the expense of the scientific and observational infrastructure that we have in place now, in terms of looking at the Earth.

It is a matter of redirecting the resources that we have, of supplementing them in critical places, and, above all, managing them wisely. And we have to put in place those mechanisms for doing just that.

It is an enormous challenge. But we are the only stewards of this planet. We cannot command Nature; we can only understand her.

It is in our power to build upon what has already been achieved with the first steps toward gaining that understanding that our children and grandchildren will most surely need.

I agree with you, Senator, Mr. Chairman, that our children and our grandchildren deserve nothing less.

Thank you.
[The statement follows:]

STATEMENT OF FRANCIS P. BRETHERTON, CHAIRMAN, NASA EARTH SYSTEM SCIENCES COMMITTEE

I welcome this opportunity to discuss with you some basic concerns about the habitability of this planet. Due to human activities, changes are taking place in our global environment that we do not understand, yet that are likely to have profound consequences for coming generations throughout the world.

A Scenario

Imagine the world in A.D. 2038 - 50 years from now. The details of this scenario are fantasy, but the types of environmental change illustrated in it are consistent with what scientists currently believe is happening around us. The task of the Global Change Program is to narrow the range of uncertainty in these predictions.

Let us start in New York City in August, where it is 95 degrees Fahrenheit outside, with 95% relative humidity - a really nasty summer day. Such weather typically starts on July 4 and must be expected to remain that way until after Labor Day. Nowadays, long and hot summers come every year.

In Alaska, on the other hand, the place is booming. The fishing industry has tripled its catch in the past ten years, thanks to changes in the ocean currents bringing in more nutrients. In Washington and Oregon the timber industry reigns supreme, supplying the world with high quality, plentiful lumber in a benign, warm climate.

In the mid-section of the country things are not so good. Throughout Nebraska, Kansas, Oklahoma, Western Texas, it is a desert. The dust bowl of the 30's has returned, seemingly to stay. The Ogalalla aquifer was mined dry 20 years ago, and there is nothing for the people to do but move. They are not going to California or to the Sun Belt, but north to Canada, where under the influence of the greenhouse warming the vast resources of the sub-Arctic are finally being opened to human settlement. Indeed, with this population explosion, the two most powerful nations on the earth are now Canada and the Soviet Union.

In the United Nations, the preoccupation is how to deal with an international cartel, that has bought up the remaining forests in the Amazon basin, in Indonesia, in Malaysia, and is holding the world to ransom. They are charging anything the world is able to pay - for some genetic material that is to be found in those forests, and only in those forests, and is critical to the development of a new fungus resistant strain of rice.

The need for a Program of Global Change Research

This scenario illlustrates the rise in temperature and changing patterns of rainfall that are associated with increasing carbon dioxide in the atmosphere due to the worldwide burning of coal and oil. Increases in methane and nitrous oxide, associated in ways that we do not fully understand with changes in land use, are also substantial contributors, as are the chlorofluorocarbons that are also implicated in the chemistry of stratospheric ozone. The priceless heritage of living species from billions of years of evolution is being decimated within a few decades in the name of economic development, and we give scarcely a thought to the possible consequences of our actions. There are other more immediate symptoms of human activities, such as the consequences of acid precipitation, the loss of productive wetlands around our coastliness, the encroachment of deserts in the semi-arid regions of the world. Each one of these is a recognized major regional issue that, however, must be viewed in the context of even more far reaching global changes in the underlying physical, chemical and biological processes that sustain the habitability of this planet.

To enable more reliable predictions of the expected changes and their schedule it is essential to improve our understanding of the functioning of the entire earth system, the atmosphere, oceans, ice, land surface and biological systems and the interactions between them. This requires a long term program of basic research into Global Change, a broadening and re-emphasis of the National Climate Program, centered upon documenting the changes that are actually occurring and identifying their causes. It is essential now to put the building blocks in place for future generations to be better able to cope with their inheritance.

Such a program is timely because of the maturation of over the past decades of the disciplines in the Earth Sciences and growing awareness of the interconnections between them. Satellites combined with selected in situ measurements can provide a new global perspective. Advanced computer and communication technologies enable both the handling of the resulting data sets and the development of numerical models that simulate more and more of the complexities of the real system. Such models can synthesize the collective experience of experts in many different areas, and permit examination of cause and effect relationships in nature. In conjunction with direct measurements, they in effect provide the diagnosis upon which any effective treatment must be based.

Yet implementing such a program also poses profound challenges to our institutions and traditional approaches to science. First is the need for scientists from many different disciplines to find new ways of working together on complex issues which transcend the professional expertise of each of them. Second is the need to sustain this effort over several decades, in particular the long term measurements and information system necessary to document unequivocally the changes actually occurring. Third is the need for the federal government to organize and fund a major research and monitoring program involving many agencies coordinated to an unprecedented degree, and to relate that program effectively to the process of decision making and policy formulation on environmental issues. Fourth is the need for a truly international framework in which the nations of the world work together to obtain a common understanding and common solutions to issues that concern them all.

In a time of severe budgetary stringency and other pressing issues, these challenges may indeed seem daunting. However significant progress is being made in initiating this program, both nationally and internationally, spurred on by the growing realization that time is not on our side. Only by starting now can we step, however falteringly, into the future.

Management Considerations

In structuring a national program on Global Change, it is essential that the basic research be loosely coupled to, but conducted separately from, consideration of policy issues. It is widely recognized that policy decisions must be made as required in light of available knowledge and uncertainties. Nevertheless, a thorough foundation of knowledge is very important to sound policy making. However a number of factors dictate a degree of separation between the policy making process and the program for acquiring the underlying knowledge. These include the long time scales for making significant progress in basic research (probably decades in this case), the realization that such progress must draw upon a wide spectrum of existing capability spread through agencies such as NSF, NOAA, NASA, USGS and others which have other responsibilities besides global change, and the imperative to keep the process of scientific discovery and assessment free from suspicion that it could be manipulated to justify any particular policy.

Stratospheric Ozone: A Case Study

The original policy issue (should the U.S. build a fleet of supersonic transports to fly in the stratosphere) became moot within a few years, but basic research stimulated by it gave rise to the discipline of Atmospheric Chemistry. From this knowledge base came recognition of the importance of chlorofluorocarbons for the chemistry of ozone, and also of the importance of methane and other tropospheric chemistry for global change.

The 1987 Montreal convention was based upon 20 years of basic research, initiated by the DOT CIAP study and continued under NASA as lead agency, which established scientific consensus about the essentials of gas phase chemistry of the stratosphere. Properly handled, government sponsored programs can greatly accelerate scientific progress.

The observation of the Antarctic ozone hole was a surprise, not explicable by consensus models 5 years ago. After a major scientific effort (built upon existing NASA, NOAA and NSF programs) it has become apparent that problem was that those models ignored interactions of the gas phase with ice crystals. It is now recognized that ice has a dominant influence in the extreme cold of the Antarctic winter (and to some extent in the Arctic). The major role of chlorofluorocarbons and nitrogen oxides seems to be confirmed, but the pathways, and hence the quantitative predictions, were wrong.

The major lesson that I draw from the ozone experience is more philosophical. It is that throughout the global change program we must expect to be surprised by nature, and continually challenged to explain phenomena that we have not had the imagination to envisage, even though in general terms they might have been foreseen. It is all too easy to become lulled into a statistical view of the world, bemused by averages and long term trends, losing track of the fluctuations and synergism that cause real change to happen in fits and starts. A forest may seem impervious to increasing acid rain and climate stress, but only up to a point, beyond which catastrophic die-back suddenly strikes. Following a severe drought things may seem to have returned to normal, masking a change in which now such droughts no longer occur once in a lifetime, but rather every decade. Even though we may think we understand something and make confident predictions replete with upper and lower bounds, in fact all our models are terribly vulnerable to processes that have been omitted when in fact they should not have been. Only when backed by solid observational confirmation over the full range of circumstances at issue should modelers predictions be treated as more than educated guesses.

Thus the credibility of a Global Change program will depend critically on long term measurement of a wide variety of global variables and the information system to go with it, backed by a wide open mind and a broad based supporting program of research into individual processes. A healthy program of basic research in the Earth sciences is fundamental. To build a Global Change Program at the expense of this existing infrastructure would probably be counterproductive, even for the Global Change program itself.

Conclusions

Growing awareneness throughout the woprld dictates commitment to a program of long term basic research into Global Change. This task poses many challenges, but these hearings and others like them are significant steps towards putting in place the foundations of knowledge that our children and grandchildren will so sorely need.

The CHAIRMAN. Dr. Bretherton, of those existing responsibilities, you did touch on NOAA and the need for a change in the nature of NOAA as an entity. Are there any other existing responsibilities that are misassigned that should be reassigned?

Dr. BRETHERTON. How to structure this program is a complex issue, and I must preface my remark by saying that I am not a member of the Federal Government. I am an outsider here. In fact, I have to admit that I am not even a citizen of the United States.

But I have been closely concerned in observing how the system works and in working with it over the last several years.

I believe the issues are fairly squarely addressed in the bill. We are talking about a broadening of the base and a reemphasis of the existing national climate program. It is essential that that activity be properly subsumed in a workable way into the new structure. I believe that the bill addresses that.

I have been impressed by the ability of the agencies to get together in an ad hoc and informal way—it is what is known as the "Senate of the interested"—and get a great deal done. But I have also been convinced that we have to have a formal structure, some centralized responsibility, some ability to cross-cut the budget and tie things together, both on the Executive side and also on the Congressional side.

I believe the specific statements in the bill go a long way to doing this. But I would hate to step in the way of my Federal colleagues who have more expertise in this matter than I do.

The CHAIRMAN. Thank you.

Dr. Peck.

STATEMENT OF DALLAS L. PECK, CHAIRMAN, COMMITTEE ON EARTH SCIENCES, FEDERAL COORDINATING COUNCIL ON SCIENCE, ENGINEERING, AND TECHNOLOGY, AND DIRECTOR, U.S. GEOLOGICAL SURVEY

Dr. PECK. Thank you, Mr. Chairman. It is a pleasure to appear before the Committee and Senator Gore, representing not the Geological Survey, but the Federal Coordinating Council Committee on Earth Sciences.

Dr. William Graham, the President's Science Advisor, formed the Committee on Earth Sciences within the Federal Coordinating Council on Science, Engineering and Technology in April 1987.

The committee is charged with coordinating all earth science activities of the Federal agencies with, and I quote, "the purpose of increasing the overall effectiveness and productivity of Federal research and development efforts directed toward an understanding of the Earth as a global system."

I was appointed Chairman of that committee in October 1987. The full committee has met three times since then, and the staff has been very active and productive.

All the participating agencies have been very cooperative and forthcoming.

The committee has senior policy-level representation from a number of Federal agencies, including the Departments of Agriculture, Commerce, Defense, Energy, Interior, and State; the Environmental Protection Agency; the National Aeronautics and Space Administration; the National Science Foundation; the Office of Management and Budget; the Council on Environmental Quality; and the White House Office of Science and Technology Policy.

The National Climate Program Office is represented on the committee at the staff working group level.

Although the committee is addressing a broad range of earth science activities, including ground water and the International Decade for Natural Disaster Reduction, it is devoting much of its energy to global change program planning.

The committee is reviewing the status both of scientific knowledge and of Federal programs related to global change, with the objective of establishing science goals and identifying key program needs. These activities are being done in close collaboration with the Committee on Global Change of the National Academy of Sciences. That committee, in turn, is closely linked to the Special Committee on the Geosphere-Biosphere Program of the International Council of Scientific Unions, or ICSU.

We expect that many countries will form groups to address global change issues in response to ICSU activities, and we plan to develop international cooperative linkages with those groups.

Our program description is proceeding well, and the agencies currently are compiling activity and budget information for the 1989 Fiscal Year in our common format and structure. We are developing a consistent set of definitions and categories of the Federal global change programs we already have. For this purpose, we are developing a crosscut matrix to describe the Federal program in global change, which the agencies currently are testing, using resource levels identified in the President's FY 1989 budget.

Similar information for the proposed Fiscal Year 1990 budget will be developed early in the 1990 budget process.

The Committee on Earth Sciences also has established a linkage with an existing interagency data group, which was convened by NOAA, to address global change data format and exchange standards, and also mechanisms for assuring that data required for global change assessments are appropriately archived, preserved, and made possible to all scientists. That committee is being led by Tom Pyke, of NOAA, and has been very productive over the last year.

Because of the peculiarly global nature of remotely sensed data, special attention is being given to its archiving requirements.

The committee is undertaking several activities to inform Federal managers on the capabilities and limitations of current global circulation models that are used to predict the effects of changes in atmospheric chemistry on global temperatures, atmospheric circulation, and

precipitation patterns. Among these activities was a May briefing for the Executive Office of the President. Dr. Leatherman, who will testify before you later this morning, will brief the committee later this afternoon on beach erosion caused by a rise in sea level.

The committee also is working with EPA and the State Department to plan the assessment of scientific knowledge of climate change and its impacts required by provisions of the Global Climate Protection Act of 1987.

Thank you for the opportunity to discuss the activities of the committee. I appreciate being invited to attend this meeting.

The CHAIRMAN. As the Chairman of that committee, Dr. Peck, are there any duplications that you know of now that we ought to eliminate?

Dr. PECK. Oh, there is probably always some duplication. Whether they are undesirable duplications is another thing.

We are just in the process of laying out this matrix. We have asked the agencies to respond, I think by July 20, with their budgetary input, so that we can lay the whole program out.

I think we will find very little undesirable overlap. I think we will find some areas where we think increased emphasis and resources are needed. I think it is going to be very useful in laying out a really good science plan for the 1990 budget.

The CHAIRMAN. Well, this initiative, S. 2614, do you find that a help or a hindrance?

Dr. PECK. I have only had a chance to glance at it, Mr. Chairman. I think it is an awfully good start. I think it does lay out the issue. The goal of the bill, it seems to me, is to institutionalize much of what we are doing on an informal basis in a Federal council right now.

The idea of laying out a 10-year plan is a good idea. As far as institutionalizing the present arrangement, I really don't know what the administration's posture will be.

The CHAIRMAN. Dr. Bretherton, you told us so many things that we do not know, and yet, it seems, as a politician, there is a lot that you scientists tell us that we do know. In other words, 40 percent of this greenhouse effect is from fossil fuels, 20 percent is from deforestation, another 20 percent is from chlorofluorocarbons, or CFCs, another 20 percent is, say, from methane and other gases. We don't know how methane is really affecting it.

But our friend, President Kennedy, used to say that the captain who waits for his ship to be fit never puts to sea.

Now, I am listening, and you are telling me, let's say as a Senator from Nebraska, that I am going to have a desert, rather than a State, 50 years from now. Why don't I do something now?

Isn't there something that can be done now, with all the knowledge that we do have on these things? Scientifically, you know, we'll wait till the end of time for you scientists to be specific and exact, 100 percent. So, we never can wait for that.

It seems to me you have a pretty good grasp of the problem whereby we could start moving in a concerted way on the burning of fossil fuels, the deforestation, stop cutting the forests and everything else of that kind, a sort of coordinated plan that is lined out to where the body politic can understand and support it and move forward on it.

Of course, the bill calls for a study and it calls for a plan. I am not talking against my own bill. But I am trying to get something moving along with that plan, or some of the things that could be done now.

What would you suggest? There is nothing really that we can do reliably, then, as you see it at this time?

Dr. BRETHERTON. Well, firstly, let me reemphasize that I don't actually know whether the mid-section of this country is going to get that much drier or perhaps even somewhat wetter under a global change.

That is an inference from our computer models, and the computer models, in fact, differ somewhat among themselves on this effect.

Now, this is a matter of some controversy in the community. I think there is a balance of present opinion that that is the way it will go; but it is certainly not overwhelming evidence. Without the observations, I think it would be very unwise to act on the assumption that that is what is going to happen 50 years from now.

This does not mean that one does not take out some insurance policies. It does not mean that you don't start to work up issues like do we really need to draw down the irrigation water at the rate at which we are doing so, or are there ways of conserving that.

There are policy options in the light of something short of certainty. What I think is most important is that we get those policy options out on the table now, recognizing that we do not really have that certainty.

And, meanwhile, we must work our tails off to try to narrow the range of the uncertainty so that we can be more sure about what is going to happen.

The CHAIRMAN. Senator Gore.

Senator GORE. Thank you, Mr. Chairman.

I am trying to contain myself.

I am sure you are a very distinguished scientist, Dr. Bretherton, and I know you probably have done great work in lots of areas. But, I'll tell you, I have listened to testimony on this issue for eight years now, and I have watched it develop, and I really found it hard to sit still during your testimony.

With all due respect, I think that if we took your recommendations or even your analysis, including that of the cartel and tropical rain forests, we would be, you know, misled.

The whole idea of winners and losers is nonsense, in my view. The Toronto Conference said the effects of global climate change are second only to the effects of global nuclear war. You say that the evidence supporting the theory is flimsy and controversial.

Are you familiar with the document produced at Villach, when was it, three years ago, and updated each year since then?

I just think that the relationship between—and I am not expressing anger at you personally, Dr. Bretherton, at all. I appreciate your coming here in response to the Committee's invitation. But the relationship between government and the scientific community is part of the problem here.

Dr. BRETHERTON. Uh-huh.

Senator GORE. We live in a unique time. In all of human history, it took millions of years for the population of this Earth to reach 2 billion; and in one lifetime it is going from 2 billion to 10 billion.

The impact of each human being is magnified by the chemical revolution, the industrial revolution, the scientific and technological developments that have occurred at an accelerating pace in this century and since the end of World War II.

This is not a flimsy and controversial theory. This is accepted.

You say that we cannot command Nature; we can only understand her. That is a sweeping statement. But, in fact, human civilization is commanding Nature right now.

Our civilization is having a larger effect on global climate than any natural cause. This whole notion of winners and losers serves merely to produce policy paralysis.

And it is nonsense—with all due respect. The idea that the uncertainties have to be eliminated before we can actually do anything is also a prescription for paralysis.

What can we do now?

Well, let's talk about CO2. As the Chairman noted, CO2 is only 40 percent of the problem. Twenty percent of the problem is due to chlorofluorocarbons, which are also the cause of a separate, but related catastrophe, destruction of the ozone layer.

Why don't we stop producing them now? We should do it for other reasons anyway.

Another 20 percent of the problem is due to deforestation. We need to stop that. We need to use debt for equity swaps in the Third World. We need to use a variety of other mechanisms to stop deforesting the Earth and, thereby, reducing our capacity to absorb CO2, and, instead, begin reforesting the Earth.

We should move toward energy efficiency. We should do that for other reasons anyway.

The talk about nuclear power, again, serves to produce paralysis in policy.

If we had a magic wand and changed all electricity production in the world tomorrow to nuclear power, I have not done the full calculations, but I daresay we would be dealing with 4 percent to 4 percent of the greenhouse effect. If CO2 production is 40 percent, what is electricity production as a percentage of energy usage?

Dr. BRETHERTON. It is about 25 percent.

Senator GORE. Well, you are looking at a small percentage of the problem.

I just wanted to express that frustration because I think that it hurts the ability of the Congress to move forward when we get that kind of testimony.

I want to give you a chance to respond and then I have a question for Dr. Peck. But I owe you a chance to respond there.

Oh, one other point before you do. The rate of change itself is just too fast for human civilization to adapt to, and that is why the whole winners and losers thing is silly, in my view. They won't benefit in Alaska or anywhere else because the climate won't stabilize for long enough that civilization can adapt to it.

The fact is, the global climate is in equilibrium, and, when we knock the climate out of that equilibrium state and it begins to search for a new one, we have continuous change, with civilization finding it extremely difficult to adapt to it. And if, as you say, the warm weather and new currents in Alaska produce better fishing, all the melted ice is going to be covering up South Carolina.

The CHAIRMAN. Why don't they both respond?

Dr. BRETHERTON. Mr. Senator, I apologize if I appeared to give the impression that I was trying to promote a winners and losers statement. That was not my objective.

I was trying to put a tinge of moderation into the most extreme statements, "the sky is falling," because I believe the scientific evidence for the greenhouse effect is very real and is not controversial. I agree completely with you and DR. White on that subject.

It is some of the third order effects that Dr. White referred to about which we are really substantially less certain, and some of those are, indeed, the things that make the most dramatic headlines. As a result, I consciously put into that scenario a mix of things.

It was really, please, intended only in that spirit.

Senator GORE. Fine.

Dr. BRETHERTON. Indeed, I agree with you completely that we have to examine the full range of policy issues that can be done, the policies that can be done now, that are likely to help, are likely to ameliorate pieces of this problem.

But my underlying message is that it is important that we do that in a way that pays due respect to the interactions between things that we do, that we do not fully understand.

Let me give you an illustration from the case history of ozone, as I see it. Some 20 years ago was when the ozone issue first surfaced, when a proposal was in front of the U.S. Government to build a fleet of supersonic transports, and some very far-seeing scientists, chemists, said oh, the oxides of nitrogen from the exhausts there could have an impact on the ozone, according to mechanisms for controlling that ozone, as we then understood it.

There was started at that time, under the Department of Transportation, a CIAP program, a Climatic Impact Assessments Program, and eventually Congress gave NASA the lead agency responsibility for the basic research in that.

Now, within a couple of years of the issue being raised, it was moot. Supersonic transports were not being built. But that attention had riveted the scientific community and put resources into a completely new discipline of atmospheric science that has gone way beyond the understanding of ozone, and, in fact, is responsible for our understanding now of methane and its importance in the system as a whole, and of the chlorofluorocarbons and the ozone problem.

Now, the message here, though, is that the Montreal Convention was based on 20 years of building a knowledge base and scientific consensus. My observation of the political process is that most decisions have to be made in less than 20 years from the time they surface. And so, the basic point is, if you are trying to gear a research program to the issue of the moment, it is probably going to be counterproductive.

That was really all that I was trying to say.

Senator GORE. I appreciate that. Thank you.

Very briefly—I have run over my time—Dr. Peck, I passed legislation as part of Public Law 99-383 that required the President to come up with a report on the current government activities with respect to the greenhouse effect. It came out of this Committee.

One of the strong recommendations of our Committee under this amendment was that you establish and set in motion an International Year of the Greenhouse Effect, using as a model the International Geophysical Year in the late 1950s, which was extremely successful, and which, incidentally, in line with the discussion you gave us of how we found out about ozone depletion, produced the monitoring station at Mauna Loa, which led to the seminal graph of CO2 increases, from—what—280 parts per million to 330 parts per million over a 30 year period. It galvanized the entire world into a new effort to study the geosphere and the biosphere.

Our Committee recommended that the administration build on that model and call for an International Year of the Greenhouse Effect to leverage the research efforts of other nations and to quickly update our data bases. Simultaneously, it would produce an increased awareness worldwide of what it is we are about to confront, what it is we are confronting now, and what we must be prepared to do in order to prevent the direst consequences from taking place.

The President replied rather curtly, "We don't plan to do that."

Why was that his conclusion? Was it your recommendation? If so, why?

Dr. PECK. Well, I did not participate in the decision leading to that.

There is a growing global awareness of climate change.

Senator GORE. Well, why did the President decide not to support it?

Dr. PECK. I can't speak for the President.

Senator GORE. Well, you are head of the council that he relies upon to coordinate policy in this area, right?

Dr. PECK. I am head of the committee to coordinate activities in this area, yes, but I was not asked.

Senator GORE. You were never asked about this?

Dr. PECK. No.

Senator GORE. Okay.

That's the way the President handles a lot of issues.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you very much.

We will keep the record open. The Committee is indebted to both of you, Dr. Bretherton and Dr. Peck. We appreciate it.

In the interest of time, now, we will call forward our scientific assessment panel: Dr. Watson, Dr. Rosenberg, Dr. Leatherman, and Dr. Hall.

Dr. Watson is with the Earth Science and Applications Division of the Office of Space Science and Applications, National Aeronautics and Space Administration; Dr. Rosenberg is the Director of the Climate Resources Program at Resources for the Future here in Washington; Dr. Stephen Leatherman is the Director of the Laboratory for Coastal Research at the University of Maryland; and Dr. J. Michael Hall is the Director of the Office of Climate and Atmospheric Research at NOAA.

Dr. Watson, can we start with you, sir?

STATEMENT OF ROBERT T. WATSON, EARTH SCIENCE AND APPLICATIONS DIVISION, OFFICE OF SPACE SCIENCE AND APPLICATIONS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. WATSON. Thank you, Mr. Chairman.

It is obviously a pleasure to be here today to talk about the global change issue.

We have heard today that the environment is changing. There is no question.

Ozone is decreasing; the globe is getting warmer.

Politicians made a significant step forward only a year ago in the Montreal Protocol, a plan to reduce the emissions of CFCs by up to 50 percent by 1999.

Senator GORE. Thirty-five percent.

Dr. WATSON. They didn't wait for certain knowledge. That's good. Even within the last year our knowledge has changed drastically. We now understand why there is an Antarctic ozone hole. It is due to man's activities—the emissions of chlorofluorocarbons. We should learn lessons from this.

The Antarctic ozone hole was unexpected, it was sudden, and the system did not respond in the way scientists predicted.

Yes, it took the unique weather, meteorology, of the Antarctic to produce this, but it took man's activities, it took the input of chlorine.

What we should recognize is even with action, even with a fully ratified Montreal Protocol, the ozone hole, in my opinion, is here forever. What would it take to get rid of the Antarctic ozone hole? Probably more than a 90 percent reduction in the fully halogenated fluorocarbons and still, in my opinion, the hole will be here for 50 to 100 years to come in the future.

The lesson is the system does not change slowly, does not always change linearly. The climate system may not change slowly. The climate system may not change linearly. We have to be careful.

There are other lessons that we should also take from the ozone story. One lesson is that we must have a separation of science and policy.

What I mean by this is there are roles and responsibilities for science agencies; there are roles and responsibilities for policy agencies.

In the ozone issue, the science was done by the science agencies, such as NSF, NASA, and NOAA; policy was driven by EPA and negotiated by the State Department. This is an excellent model which we should build upon for the climate issue.

One of the problems with science, when driven by policy on a day to day level, is one does not have a broad enough policy perspective or science perspective. So I personally believe that we should look very carefully at the lessons learned from the ozone issue.

We have also learned something else since the Montreal Protocol only a year ago, and that is that ozone is changing in the Northern Hemisphere. It cannot be explained by natural phenomena, as we understand it today. The changes are greater than we predicted.

The question here, quite clearly, is have we underestimated the impact of the CFCs in the Northern Hemisphere, where people live? NASA and NOAA are going to have an active campaign to try to understand why ozone is changing in the Northern Hemisphere next year, in January and February, from Stavenger, Norway.

Clearly, what we have here is an issue where we understand that CFCs are destroying ozone, but without perfect knowledge. This does not mean to say one cannot have strong policy action.

In the climate issue, it is clear that the temperature record is increasing—totally consistent with the issue of the greenhouse warming. We have some uncertainties. But that is not to say that there should not be policy actions today.

I agree completely with both of you on that issue. I also agree there are no winners and only losers. The conference in Canada last week clearly showed that.

I believe the political security of the nation and of the globe is significantly threatened by a major change in climate.

But there are uncertainties. Even if one has a policy, where one cuts back on fossil fuel or changes the fuel mix—excellent things to do—independent of a climate warming, and in my opinion, yes, we can cut back on CFCs. But there are gases, such as nitrous oxide and methane, that are increasing in the Earth's atmosphere. We do not understand today why methane is increasing and we don't understand why nitrous oxide is increasing.

So, even if you have a policy to try to decrease the rate of increase of carbon dioxide in the Earth's atmosphere or CFCs, that is not the whole solution. We must have an active research program to try to understand why methane is increasing, why nitrous oxide is increasing. It is not until we understand why those gases are increasing that we can even consider regulations.

So, quite clearly, at the moment there are things that policymakers can do to do with carbon dioxide, to do with fluorocarbons, but, at the moment, we have a significant lack of knowledge regarding methane and nitrous oxide. The only way we are going to understand those issues is a holistic earth sciences program: how does the atmosphere, the oceans, and the terrestrial biosphere interact? It will need an international program. It will require process studies at the ground level, and it will require satellite observations.

We need a commitment to long-term science programs.

I think this has to be the way to go.

There are many things we learned basically in the ozone issue. Another one was that when we do scientific assessments, don't make them national assessments. Mandate them international assessments. It is only by getting the international science community together for an international assessment that that scientific base will be accepted by all countries.

We had many false starts in the ozone story. We had national assessments in America, in the Soviet Union, in Germany, and what we mainly argued about was the difference between the assessments. After a while, we recognized the folly of our ways and that we needed to have international assessments for ozone. That must be the model we use for climate.

So, to summarize, there are many things that we should be concerned about. The environment is changing, largely due to man's activities. However, while we can move ahead in some areas in policy, there are other areas where we are stymied, due to lack of scientific knowledge. We need dedication to a holistic earth sciences program. It must be international in scope and it must be long-term.

Thank you.

[The statement follows:]

STATEMENT OF

DR. ROBERT T. WATSON

BEFORE THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

U. S. SENATE

Mr. Chairman and Members of the Subcommittee:

I am pleased to be here today to discuss the current state of knowledge concerning the processes which control the chemical composition and physical structure of the Earth's atmosphere, and the type of information needed to improve our understanding. While there are many changes in the Earth's atmosphere which are currently of concern, I will focus on the issues of stratospheric ozone depletion and global climate warming.

SCIENTIFIC BASIS FOR CONCERN:

It is evident that the Earth is a planet characterized by change. We have entered an era in which the human race has achieved the ability to alter its environment on a global scale. The ozone and global greenhouse warming issues which are presently at the center of attention of many scientists and policymakers are just two of the interrelated environmental issues we face today.

To gain a scientific understanding of how human activities will affect the Earth's environment requires a new approach to Earth sciences. We need to obtain a scientific understanding of the entire Earth system on a global scale by describing how its component parts and their interactions have evolved, how they function, and how they may be expected to continue to change on all time scales. In particular the immediate challenge is to develop the capability to predict those changes that will occur in the next decade to century, both naturally and in response to human activity. This will require a nationally and internationally coordinated program of interdisciplinary research to investigate long-term, 10-100 years, coupled physical, chemical, and biological changes in the Earth's environment recognizing that land, atmospheric, oceanic, and biospheric processes are strongly coupled on a variety of temporal and spatial scales.

For several decades scientists have sought to understand the complex interplay among the chemical, radiative, and dynamical processes that govern the structure of the Earth's atmosphere. During the last decade or so there has been particular interest in studying the processes which control the total column amount and vertical distribution of atmospheric ozone, and climate. Ozone is the only gas in the atmosphere that prevents harmful solar ultraviolet radiation from reaching the surface of the Earth. Unlike some other more localized environmental issues, e.g. acid deposition, ozone layer modification and global greenhouse warming are global phenomena which affect the well-being of every country in the world. Changes in the total column amount of atmospheric ozone would modify the amount of biologically harmful ultraviolet radiation penetrating to the Earth's surface.

The ozone issue and the greenhouse warming issue are strongly coupled because ozone itself is a greenhouse gas, and because the same gases which are predicted to modify ozone are also predicted to produce a climate warming. These gases include carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), several chlorofluorocarbons (CFCs), including chlorofluorocarbons 11 ($CFCl_3$), 12 (CF_2Cl_2) and 113 ($C_2F_3Cl_3$), and Halons 1211 (CF_2ClBr) and 1301 (CF_3Br). CH_4, N_2O, the CFC's, and the Halons, respectively, are precursors to the hydrogen, nitrogen, chlorine, and bromine oxides which can catalyze the destruction of ozone in the stratosphere by a series of chemical reactions.

There is now compelling observational evidence that the chemical composition of the atmosphere is changing at a rapid rate on a global scale (see Table 1). The atmospheric concentrations of CO_2, CH_4, N_2O, and CFCs 11 and 12 are currently increasing at rates ranging from 0.2 to 5.0% per year. The concentrations of other gases, including CFC 113 and Halons 1211 and 1301, important in the ozone and global warming issues are also increasing, some at an even faster rate. These changes in atmospheric composition reflect in part the metabolism of the biosphere and in part a broad range of human activities, including agricultural and combustion practices. It should be noted that the only known source of the CFCs and Halons is industrial production. They are used for a variety of uses, including aerosol propellants, refrigerants, foam blowing agents, solvents, and fire retardants. At present one of our greatest difficulties in accurately predicting future changes in ozone or global warming is our inability to predict the future evolution of the atmospheric concentrations of these gases. We need to understand the role of the biosphere in regulating the emissions of gases such as CH_4, CO_2, N_2O, and methyl chloride (CH_3Cl) to the atmosphere, and we need to know the most probable future industrial release rates of gases such as the CFCs, Halons, N_2O, CO, and CO_2 which depend upon economic, social, and political factors. Although the rates of change of the trace gases are well documented, the underlying reasons for the changes are not. Consequently, it is essential to improve our current understanding of the geophysical and biological processes that control the transfer of these trace gases into and out of the atmosphere from the aquatic and terrestrial biosphere. This will require an improved understanding of the processes which control the fluxes of gases such as methane into and out of ecosystems, and precise knowledge of the areal extent, and rate of change of areal extent, of the relevant ecosystems.

One important aspect of the ozone and global warming issues is that the atmospheric lifetimes of gases such as N_2O, $CFCl_3$, and CF_2Cl_2 are known to be very long. Consequently, if there is a change in atmospheric ozone or climate caused by increasing atmospheric concentrations of these gases the full recovery of the system will take several tens to hundreds of years after the emission of these gases into the atmosphere is terminated.

In many ways predicting climate change is much more difficult than predicting changes in the ozone layer. However, while for some aspects of the climate issue our current knowledge is more rudimentary and the issue more complex, in others the greenhouse warming issue is actually simpler than the trace-gas ozone issue. While we are far from a complete understanding of the magnitude and timing of climate changes due to increasing concentrations of trace gases such as CO_2, CH_4, N_2O, and the CFCs it is clear that these gases absorb infra-red radiation and hence change the radiative balance of the atmosphere.

Because it is now well recognized that the chemical effects of these gases on atmospheric ozone are strongly coupled and should not be considered in isolation, the most realistic calculations of ozone change take into account the impact of simultaneous changes in the atmospheric concentrations of CO_2, CH_4, N_2O, the CFCs, and possibly other gases such

as CO, oxides of nitrogen (NOx), and bromine containing substances. The effects of these trace gases on ozone are not simply additive.
From the ground-based observations made at the McMurdo station in 1986 and from the ER-2 and DC-8 aircraft campaign based in Punta Arenas in 1987, the weight of observational evidence very strongly suggests that chemical mechanisms involving man-made chlorine are the primary cause of the rapid decline of ozone during September within the polar vortex. The unique meteorology of the region sets up the special conditions of an isolated air mass (polar vortex) with very cold temperatures that is believed to be required for the unusual chemical mechanisms.

The ground-based and aircraft data demonstrated that the chemical composition of the Antarctic stratosphere in springtime is highly perturbed compared to that expected at these latitudes based on measurements at mid-latitudes and predictions using chemical models that predate these new data. The distribution of chlorine among various molecular species is ver different from that observed at mid-latitudes, as is the abundance and distribution of nitrogen species. In addition, regions of the polar vortex are severely dehydrated.

There are two processes currently not included in photochemical models that might provide explanations for these two observations: (1) the observation of winter-time ozone decreases in the northern hemisphere might be explained by heterogeneous chemical processes, while: (2) the observation of year-round decreases in ozone outside of the polar vortex in the southern hemisphere might be explained by a "dilution effect" from the spring-time Antarctic ozone hole.

In order to understand what initiates changes in climate or stratospheric ozone requires an understanding of the forcing functions of the system and the planetary response processes.

The forcing functions of the climate system and stratospheric ozone are both natural, including changes in solar irradiance, and anthropogenic, including increases in the atmospheric abundances of trace gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs).

The planetary response processes which need to be understood to predict changes in the Earth's climate include:

(1) the water vapor greenhouse feedback,
(2) the ice-albedo feedback,
(3) cloud feedback,
(4) aerosol (natural and anthropogenic) - cloud interactions
(5) ocean - atmosphere interactions
    - heat capacity - ocean circulation
    - sea surface temperature - atmospheric circulation - precipitation
(6) land (soil and vegetation) - atmosphere interactions
(7) trace gases and the biosphere: sources and sinks
(8) tropospheric chemistry
(9) stratospheric chemistry
(10) radiation balance

To predict changes in stratospheric ozone requires an understanding of a major sub-set of the above.

A vital component of a National Climate research program is the utilization of space technology to understand the processes which control the earth's climate system and its

sensitivity to natural and man-induced changes and to assess the possibilities for climate prediction on time scales of from about two weeks to several decades. Because the climate is a complex multi-phenomena system, which interacts on a wide range of space and time scales, the diversity of scientific problems addressed requires a hierarchy of models along with the application of modern empirical and statistical techniques which exploit the extensive current and potential future global data sets afforded by space observations. Observing system simulation experiments, exploiting these models and data, will also provide the foundation for the future climate space observing system..

The principal activities that comprise nearly all research programs include: (1) the development and deployment of satellite-based observing systems; (2) the collection, processing, and analysis of satellite observations; (3) the development and application of techniques for extracting parameters from remote (satellite-based) measurements; (4) field experiments, where observations are made from surface, aircraft, and balloon platforms, usually to validate or support the satellite observations or technique development activities; and (5) the theoretical analysis and numerical modelling of physical processes affecting the radiation field and climate.

Aside from the obvious need for improving models in general, e.g., improved parameterization for sub-grid-scale phenomena and interactions, and in numerical efficiency factors, an expansion in the study of climate processes is vital. Quantitative assessment of relative roles of competing forcing and feedback mechanisms, as well as the myriad of climate system internal fluctuations is essential in analyzing the potential climatic impact of man-induced changes such as the trace constituent composition of the atmosphere, e.g., CO_2, CH_4, $CFCl_3$, CF_2Cl_2, and tropospheric O_3, and in land surface properties.

Major international planning is underway concerning characterizing the nature of cloud-radiation feedback and on understanding the role of the oceans as a thermal buffer and major source of internal climate variability. Other important research involves the planetary boundary layer processes, particularly with regard to tropical energetics and latent heat transport to extra-tropical regions. Progress in the latter is dependent on the improvement of coupled ocean-atmosphere models, first with the ocean mixed layer for short-range problems such as the El Nino phenomenon, and subsequently with the deep ocean for studies of long-range climate change.

Information contained in the global data sets acquired by remote sensing from satellites can provide a unique resource for defining initial state and boundary conditions for model experiments, serve as a factor in model output verification, and provide valuable insight into subtle relationships and teleconnections among climate variables, which can then be explored in detail with the sophisticated numerical models.

It is clear from the previous discussion that to document and understand global climate change will require data on a multitude of parameters from cloud cover, radiation balance, precipitation, and atmospheric and oceanic circulation to vegetation type and density, atmospheric trace gases, and ocean primary productivity and chemical and biological fluxes at the boundaries of land, ocean and atmosphere. Current NOAA, ESA, Japanese and Indian operational satellites produce routine data products that need careful validation of a number of parameters including cloud cover, sea surface temperature, atmospheric temperature profiles, vegetation index, and ice cover. The International Satellite Land Surface Climatology Program (ISLSCP) is planning to produce validated data sets on surface albedo, land surface temperature, vegetation cover, and evaporation and transpiration. A number of research satellite missions during the last decade, including the Nimbus series, Seasat, GOES, and shuttle based tests of instruments have demonstrated an ability to measure a wide range of parameters including, ocean primary productivity, surface

winds, ocean currents, sea ice, radiation budget, solar flux, stratospheric aerosols, ozone, and numerous stratospheric gases. However, there are still other measurements including precipitation, tropospheric composition, and soil moisture which have not yet been adequately demonstrated, thus requiring further technique studies.

In order to obtain the required global data sets will require continued operational space measurements from both polar orbits and geostationary, special research and new operational missions such as ERS-1, UARS, TOPEX/POSEIDEN, MOS-1, etc., and in-situ validation and calibration together with sophisticated data/information systems. It is clear that if we want to understand the natural variability of the system and differentiate it from human induced changes then special attention must be paid to calibration and continuity of global data sets.

SUMMARY

In summary, it is clear that significant progress has been made in our understanding of the physical and chemical processes that control the distribution of ozone and the temperature structure of the atmosphere. However, we must recognize that significant uncertainties in our knowledge remain, and that these can only be resolved by a vigorous program of research. Given what we know about issues such as the ozone and greenhouse warming we should recognize that we are conducting a global scale experiment on the Earth's atmosphere without a full understanding of the consequences. The Antarctic ozone phenomenon which was completely unexpected vividly demonstrates that the environment does not always change slowly, linearly, or predictably in response to a perturbation. Understanding these and related issues should clearly be a priority for the scientific and policy communities. This will require a comprehensive coordinated national and international research effort. Wise policy decisions require an improved understanding of the way in which the Earth's environment varies naturally and in response to human activities.

Satellite data, if well calibrated and continuous, can provide the data sets required to document and understand global climate change. At present the ability to measure many of the needed ocean, land, and atmospheric parameters has been demonstrated. However, there are presently very few global data sets, satellite or ground-based, of the quality and length necessary to contribute to documenting global change. If we wish to have available, in the future, a documented data-base of global change, we must begin now to establish those systems that will obtain the required comprehensive data.

TABLE 1

Coefficients of Multiple Regressions to Re-analyzed Dobson Total Ozone Measurements Collected into Band Averages (total percent changes for period 1969-1986)+

	LATITUDE BAND		
MONTH	53°-64°N	40°-52°N	30°-39°N
JAN	- 8.3±2.2	- 2.6±2.1	- 2.2±1.5
FEB	- 6.7±2.8	- 5.0±2.2	- 1.2±1.9
MAR	- 4.0±1.4	- 5.6±2.3	- 3.5±1.9
APR	- 2.0±1.4	- 2.5±1.7	- 1.7±1.3
MAY	- 2.1±1.2	- 1.3±1.1	- 1.7±0.9
JUN	+1.1±0.9	- 1.8±1.0	- 3.3±1.0
JUL	+0.0±1.1	- 2.2±1.0	- 1.3±1.0
AUG	+0.2±1.2	- 2.4±1.0	- 1.0±1.0
SEP	+0.2±1.1	- 2.9±1.0	- 1.0±0.9
OCT	- 1.1±1.2	- 1.5±1.5	- 0.9±0.8
NOV	+1.5±1.8	- 2.4±1.3	- 0.1±0.8
DEC	- 5.8±2.3	- 5.5±1.7	- 2.1±1.1
ANNUAL AVERAGE	- 2.3±0.7	- 3.0±0.8	- 1.7±0.7
WINTER AVERAGE**	- 6.2±1.5	- 4.7±1.5	-2.3±1.3
SUMMER AVERAGE***	+0.4±0.8	- 2.1±0.7	- 1.9±0.8
QBO*	- 2.0±0.6	- 1.3±0.6	+1.9±0.6
SOLAR*	+1.8±0.6	+0.8±0.7	+0.1±0.6

* per cycle minimum to maximum.

** winter months include December to March, inclusive.

*** summer months include June to August, inclusive.

+ All uncertainties given in this table and throughout this report represent one standard error. The total uncertainty in the linear trends for total column ozone (1969 - 1986) can be calculated by combining the standard errors given in this Table with a systematic error of 0.5% by taking the square root of the sum of their squares. The uncertainties shown in this Table increase by 0.2% or less.

The CHAIRMAN. Thank you.

Dr. Rosenberg.

STATEMENT OF NORMAN J. ROSENBERG, SENIOR FELLOW, DIRECTOR, CLIMATE RESOURCES PROGRAM, RESOURCES FOR THE FUTURE

Dr. ROSENBERG. I am going to use slides. Senators, and I may need a little bit of help for a moment.

Thank you, Mr. Chairman.

[Slide shown throughout the statement [1] presentation.]

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[1] See U.S. Agriculture in a Global Setting, Chapter 13, p. 203.

Dr. ROSENBERG. I was invited to talk with you about drought, climate change, and agriculture. In the written testimony that I have brought with me, you will see many of the figures that I am going to show here.

The CHAIRMAN. You may highlight as you wish.

Dr. ROSENBERG. Thank you.

I would like to remind those present that drought is a recurrent phenomenon in the United States and in North America, generally. This picture, from the drought of the 1930s, is a classic, just to set the mood.

We are very vulnerable to the impacts of drought in terms of our grain production in this country, and this graph illustrates that point. Wheat yields around 1920 were in the order of 10 or 15 bushels. The drought of the 1930s is shown in the first block.

The depression in wheat yields was obvious during the 1930s, but even more consequential, perhaps, was the number of acres planted but not harvested.

Yields rose until the drought of the 1950s, which actually seems to have occurred a little bit after a drop in yields. In a moment I will show how these droughts differed in severity and geographic extent Clearly, however there has been a general increase in wheat yields in the Great Plains, from the 1920s until today.

This is a graph showing the Palmer moisture anomaly index for August, 1936. Notice that extreme drought covered at least a third of the country, perhaps more.

This was the drought of 1955, August, 1956. The drought was primarily in the Southwest.

Now, August is not necessarily the most important month for the wheat crop, but I show it in order to make a comparison with the next drought.

Wheat yields rose from after the Second World War, except for the 1950's drought period, until, suddenly, we came to a drought in 1974 and again in 1976. Although quite short, this drought was severe, and it had a very significant impact on overall yields. But, by this time, we were producing 30 bushels per acre and the impact was perhaps not as great in terms of the total granary of the country. Yet it was very significant economically, coming after the 1972 grain trade with the Soviet Union which had reduced our food stocks significantly.

Note in this chart that the 1970's drought was centered in the northern plains of Minnesota and extended to Michigan in the East and to California in the West.

Geographically the three droughts differed considerably. Their impacts have been different. Their severity has been different. But we are vulnerable still, despite our improved technology, to changes caused by severe weather.

Now, to the climate change issue which has been explained very well by previous speakers. I will point out that the global climate models on which we are relying for insight, as to the future impacts of climate change differ considerably in their predictions of what will happen.

In this slide I show the predictions of future climate for North America and Africa made by three leading U.S. climate modeling groups—the Geophysical Fluid Dynamics Laboratory, the Goddard Institute for Space Studies, and the National Center for Atmospheric Research.

The stipple indicates a reduction in soil water during the summer season. What I really want to point out is that these models differ markedly, and, for any particular region—say Nebraska—you can find a model which will support virtually any future (e.g. deserts or Dr. Bretherton's paradise).

Coming from Nebraska, I am sensitive to Dr. Bretherton's remarks.

These predicted changes could lead to any number of possible impacts. I just list four here—warming in the high latitudes, which might change the Boreal forest to some extent; midsummer drying in the mid-latitudes, which could cause the Midwestern corn belt and the Great Plains wheat belt to shift. The northward advance of the monsoonal rainfall in the Sahel is one of the possible short-term benefits. That is a region that might actually have a better climate than it has today. Changes in the hydrologic cycle and availability of water supplies are also possible—indeed, likely.

Everything about the natural resource base is going to change if the climate changes in the ways that are predicted.

There is one matter that we know with greater certainty, however—and that matter has not been discussed today. Carbon dioxide, although ionly half or so of the greenhouse problem, does have some distinctly beneficial effects on plants. These effects have been demonstrated in greenhouse and growth-chamber studies: Increased photosynthesis and growth of C-3 plant species (small grains, legumes, most trees and grasses); decreased water use in essentially all of the plants that we know about, C-3 and C-4 species (corn, sorghum, sugar cane); increased water use efficiency, which means more photosynthesis for each unit of water consumed. Further, CO2 enrichment of the air offsets the detrimental effects of soil moisture stress, soil salinity, and of nutrient shortage to a certain degree.

These effects are certain. The question is whether these effects are actually occurring now because, after all, CO2 has increased by 25 percent in the last century or so, and will they occur in the future with further increases in atmospheric CO2 concentration?

I feel that, if these effects can occur in the open field, then, in the near-term they will possibly offset some of the detrimental effects of climate change, and they may also permit some of the more beneficial effects of climate change to be capitalized upon.

But, as my concluding remarks will show, I think, sooner or later, we run out of room for these effects to be very consequential.

This shows the effect of CO2 concentrations. Doubled CO2 concentration has increased the yield in experiments of cotton, peas, sweet potatoes, soybeans, sorghum and corn by approximately 80 percent to 10 percent in the case of corn.

This is reliable information.

A point I would like to make now is this. We are going to experience a climate change. I am fairly confident of that. But we already have that change in the mill, to a certain degree. No matter what we do to reduce fossil fuel emissions, we are going to have to adjust to some degree of change over the next 50 years, and perhaps more.

I think it is also very well understood that we cannot switch immediately to shut off all fossil fuels. That just is not in the cards.

This next slide is to show to you that there is a considerable amount of flexibility in our agricultural systems and potential to assist adaptation to change in our science. The yellow line represents the boundary of the hard red winter wheat zone in the United States in 1920; the pink represents the boundary of that crop in 1980. The extension of that crop is continuing into Canada today.

Hard red winter wheat has distinct advantages over spring wheat, and that was seen very nicely this year. The winter wheat growers have done reasonably well, except where conditions were so dry last fall that they could not plant that crop. The spring wheat growers are taking it rather badly this year.

This expansion of the hard red winter wheat crop occurred over a climate gradient of about 4 degrees Celsius. In other words, in Sydney, Montana, the mean annual temperature is 4 degrees lower, the rainfall is 20 percent less and the growing season is at least 10 days shorter than in Nebraska.

This expansion was into a cooler climate. But you also see that the crop advanced into a warmer climate as well. There is a great deal of flexibility in what we can do in agriculture. But I don't want to oversell that and suggest that all of the potential problems of climatic change can be handled.

There are many interesting technologies that provide some opportunity for adaptation to a greenhouse-indicated climate. Here is a nice one from Montana.

You see good snow cover over only a portion of this wheat land. This is because of rye grass being grown in the wheat field. The rye grass serves as a windbreak and captures the snow, making more moisture available for planting wheat in the spring.

Finally, you can see how good the wheat looks in the summer. This is just one example of micro-climate modification which allows adaptation to some of the stresses that we may experience even more in the future.

With your permission, I would like to summarize my major points and say, first, that it is too early, in my opinion, to encourage specific policies aimed at changing the face of American agriculture in preparation for climatic change because we don't know exactly what is going to be happening. But sound, proven practices, such as removing land from cultivation on the margins of the semi-arid zone, should be encouraged.

The implicit subsidies for mining groundwater in the Ogalala Formation that encourage wasteful use of irreplaceable water should be discouraged. There are things we can be doing now. There are logical

ways of adjusting better to climate, even as it is today, let alone as it might be in the future.

Although it is too early to be changing American agriculture, it is certainly not too early to begin systematic, orderly, and rigorous study of the vulnerability of our agriculture, the possible impacts on agriculture of climatic changes described in credible scenarios, and the technical options that may be required if we are to cope with such changes.

On the basis of such studies, and as the evidence becomes stronger and the specificity of regional projections greater, a sound set of policy options can be developed.

Whatever the rate and nature of the changes, by the time we know what is happening, world and U.S. agriculture will be far different than they are today. Therefore, it is very important that our research and our policy thinking not be based on the imposition of a future climate on today's agriculture, which is essentially what most of us have been looking at. "If the climate changes according to this scenario, then the corn belt of today would be someplace else."

We have to consider that agriculture is dynamic and that the world economy is dynamic and that 50 years from now and on the way to this milestone of 50 years from now, many things will be changing, including technology, demand for commodities, and so on.

So I suggest that serious attempts be made to forecast the kinds of agriculture, the needs for commodity production and the technological tools that will be available to us when and as climate actually changes.

I would like also to point out that in this country and the developed world in general, we have strong capability to adjust to change. But this is not true of the developing countries by and large, and in all of the assistance work that we do in our aid programs, we should be considering climate change as a factor. This is because those countries, even if the changes are benign, are going to have much more difficulty adapting.

Finally, I would like to say that climate change will be a lottery. The state of the science is yet too primitive to allow for a reliable prediction of which nations and regions within nations will be net beneficiaries and which net losers.

The implications for agriculture are two-fold. First, comparative advantage in the production of particular crops may shift from one nation or region to another. The best insurance is readiness to introduce new crops to replace those that can no longer be produced profitably.

Second, if climate change continues unabated, we will all be numbered sooner or later among the losers.

Thank you.

The CHAIRMAN. Thank you, Dr. Rosenberg.

OPENING STATEMENT BY SENATOR PRESSLER

Senator PRESSLER. Mr. Chairman, I have a statement that I want to make a part of the record. I also have some questions for the record.

Mr. Chairman, I am pleased to be an original cosponsor of the National Science and Technology Policy Amendments of 1988. You have eloquently and correctly stated the immediate need for an understanding of the global changes which are now occurring and which are predicted to accelerate in the future unless we do something now.

Crops are dying in a drought which is truly nationwide. The global mean temperature, if it continues at the present rate, will be higher this year than at any time since recordkeeping began. The ozone depletion in the atmosphere continues at an alarming rate. These and other significant changes in the earth's environment require a national and international commitment to research and damage control.

As a South Dakotan, I have seen firsthand the devastation caused by the current drought. I only hope that ten or fifteen years from now, we don't look back on 1988 as the first in a series of perennial drought years. The global climate is changing for the worse. It is incumbent upon us to find out as soon as possible what we can do to slow down or stop this potentially disastrous course.

I strongly support current and planned efforts through NASA, NOAS, and other agencies to research the effects of global change. This legislation, I believe, will assist, coordinate, and promote these actions. The bill's language stresses the importance of long-term data bases. In fact, the most essential element of global change research is the acquisition, maintenance, processing, archiving and retrieval of data.

The Earth Resources Observation System (EROS) Data Center, a facility devoted to remote-sensing data archiving and processing, is located in my home State of South Dakota. This center has been archiving and distributing land remote sensing data since 1973. Public Law 98–365 called for the establishment of a National Satellite Land Remote Sensing Data Archive at the EROS Data Center. On March 16 of this year, the U.S. Geological Survey and NASA entered an agreement to use that facility for processing, distributing, and archiving land remote sensing data acquired by NASA's research and development and experimental activities, including the Earth Observing System (EOS) component of the Space Station Polar Platform projected to be operational by the mid-1990s. The EROS Data Center continues to process and archive data collected from the Landsat satellites, which will be of great importance as a historical data base for all future global change research.

Mr. Chairman, thank you for focusing the committee's attention on this issue and holding this hearing. I would like to submit for the record a background paper describing the work done at the EROS Data Center in the area of global change research and suggesting the establishment of a National Earth Science Data Center to preserve existing and future global change data.

BACKGROUND PAPER ON A NATIONAL EARTH SCIENCE DATA CENTER

In recent years, Earth scientists have become increasingly aware that the Earth is an integrated system, whose component parts—the atmosphere, the oceans, the rocks and soils, the ice masses, the biota, etc.—are far more dynamic and interrelated than previously recognized. Complex interactions of these components have been profound effects on the evolution and history of the Earth, and they have resulted, and will continue to result, in global-wide change that will strongly influence our future quality of life, and ultimately, man's long-term survival on this planet. Fur-

thermore, man is now contributing to processes of global change in ways that could significantly alter his environment within a few generations.

Key to avoiding change that could detrimentally alter human history is obtaining a scientific understanding of the entire Earth system on a global scale by describing how its component parts and their interactions have evolved, how they function, and how they may be expected to continue to evolve. Developing the capability to predict the changes that will occur in the next decade to century, both naturally and in response to human activity is the objective. These are the fundamental elements of a rapidly evolving scientific movement that is known most commonly by the term "global change".

Studying and understanding the Earth and how its processes operate will require that a broad spectrum of globally acquired ground-based and, particularly, space acquired earth observations data be collected on a repetitive and long-term basis. The world's interdisciplinary Earth science community must analyze and interpret this data in the process of detecting, monitoring, and accessing the long-term effects of natural and man-caused global change. A few global data sets that are well-suited for the required studies currently exists (for example, Landsat data), and more are being acquired. However, global data sets best suited for the required studies will become available in great volume with the launch of the first Earth Observing System (EOS) Space Station Polar Platform in the mid-1990s. In order for the world's Earth science community to accomplish these goals and objectives, it is imperative that efficient high-volume data processing and data handling systems be ready to produce and distribute appropriate data products.

The attributes which characterize the U.S. Geological Survey's EROS Data Center (EDC) represent a capability in land remote sensing, Earth science data handling, and the interdisciplinary study of the earth that is unique. They are attributes upon which a National Earth Science Data Center, that would meet the land science data and information needs of U.S. and foreign scientists, provide scientific and technical assistance for effective use of Earth science data, and develop new data handling technologies, could be established. The important attributes of EDC include 15-years experience in satellite data processing and data handling as the principal archive, processor, and distributor of Landsat data. EDC is also the designated site of the legislatively mandated National Satellite Land Remote Sensing Data Archive, and operationally receives, processes, and distributes to research scientists data from the NOAA AVHRR sensor. EDC archives and distributes a variety of ground-based Earth science data, and has formally agreed with NASA to process, archieve, and distribute data collected by the EOS Polar Platform land data sensors and other experimental sensors in the Space Station timeframe. EDC maintains and operates a broad spectrum of advanced computer processing systems, a large, state-of-the-art photographic processing and product generation laboratory, and employs a staff that includes more than 100 research scientists and analysts with expertise in the full spectrum of Earth science disciplines. EDC has developed and implemented an extensive external communications network, and it is ideally located for direct reception of satellite transmissions.

It seems clear that the mid-1990's, with the launch of EOS, will mark the beginning of the era of optimum productivity for global change studies. Nevertheless, the years between then and now are important to ensuring that we are prepared to appropriately handle and utilize EOS data, but also as a time to initiate important studies of the Earth and its processes. Steps to establish a National Earth Science Data Center must begin now. The historical Landsat data archived at the EROS Data Center as part of the National Satellite Land Remote Sensing Data Archive contain a wealth of information that can be used to determine baseline conditions for many processes, problems, and phenomenon that will be the subjects of global studies for years to come. Programs must be implemented now to ensure that those data and information are preserved.

The CHAIRMAN. Dr. Leatherman.

STATEMENT OF STEPHEN P. LEATHERMAN, DIRECTOR, LABORATORY FOR COASTAL RESEARCH, UNIVERSITY OF MARYLAND

Dr. LEATHERMAN. Thank you, Senator.

I was asked today to speak about the impact of climate-induced changes on coastal areas, and I brought with me some slides that I would like to use to illustrate the points.

In general, let me say that a significant portion of the world's population lives within the coastal zone, with many buildings and facilities built at elevations less than 10 feet above sea level.

The general effect of sea level rise on coastal lowlands is to induce landward retreat. This translates to beach erosion and loss of marshlands.

So, if I may, I would like to show the slides which I think would illustrate these points.

The CHAIRMAN. Yes, sir.

[Slides shown throughout statement presentation]

Dr. LEATHERMAN. Senators, first of all, I might say that sea levels have changed remarkably over geologic time. Only 15,000 years ago, you would have had to go 100 miles from Charleston, South Carolina, to reach the ocean. That was during the time that we call the Ice Age.

So, the reason I provide this background information is to give the idea that the shifts in the seas, that we are seeing now, which are being driven by climate change, are what is to be expected. In other words, only a small change in climate would change the sea level considerably and would shift the shore lines great distances.

This is some data from NOAA which shows a change in sea level along different parts of the East Coast of the United States.

Here we have Charleston, South Carolina, for reference, where the sea levels have risen about 18 inches during the last century. A little less than half of is amount is attributable to climate warmind guring the past century. The trend everywhere on the East and Gulf Coasts has been up.

There are, of course, regional effects as well.

If you look at the prediction of future sea level rise, based on global climate models, the ranges go from about two feet to maybe as much as ten feet during the next hundred years. In terms of mid-range, conservative estimates, the rise will amount to between three and five feet in the next hundred years.

Now, I want to show you the impact of the last century's one foot rise in sea level on marshlands and beaches. In other words, where do we stand today, and what have been the impacts of a one foot change in sea level. Then we start thinking about what is going to happen in the future with three to five and maybe ten feet of sea level change on our coastal environments.

First, let me say a few words about coastal marshes, which are very important in the United States in terms of serving as the base for the estuarine food change and important fisheries.

This is a typical marsh in the mid-Atlantic area.

One thing that ids apparant is that our marshes are already starting to erode. This is a marsh on the Outer Banks of North Carolina; it used to extend further out into the bay. It is being cut back, and you can

see tree stumps that are left standing in the water as the erosion proceeds.

This is not the major way in which marshes are being lost nationwide. You have probably heard quite a bit about marsh losses in Louisiana, where 40 square miles per year are being lost. Our recent studies in the Chesapeake Bay show that the marshes are being lost, as in Louisiana, by interior ponds opening up. What this means is that the marsh surface, which is delicately balanced with the sea levels, is losing ground. In other words, the seas are coming up too fast already, and the marshes are not keeping pace; they are not keeping their heads above sea level.

This series of photographs graphically illustrates the problem of wetlands loss in Maryland at Blackwater Wildlife Refuge. From 1938 to 1979, one-third of the marsh was lost. The marsh is deteriorating like wetting a tissue with relative sea level rise, and the land is disappearing. About 5,000 acres of marsh has been lost in the last 40 years.

So, you might ask the question where do the marshes come from and where are they going. Most of these marshes began forming about 5,000 years ago—that is, the large expanses of marshes, as the rate of sea level rise slowed down. Broad areas of marsh then began developing. The problem is that sea level will be rising at rates not witnessed in over 5,000 years, and the marshes will be drowned. Already we are starting to see this happening.

The other problem is coastal development in low lying areas. This is a critical problem for many coastal areas, like South Carolina, where houses are now properly located on the uplands, but will be in the floodplain with rising sea levels. To protect these houses, dikes, bulkheads, etc. will be built.

As the sea level rises, some marshes can be preserved by lateral and hence upward migration with the rising water. But with buildings and houses on their landward flank, these marshes will be squeezed out of existence. This is a problem already being experienced in some areas.

Along Galveston Bay, many bulkheads have been built. This particular area was abandoned (indicating), and now salt marsh grass and fiddler crabs inhabit the yard of this house. Over a thousand houses were abandoned in this area. This is an artificial problem due to the land actually sinking due to the withdrawal of oil, gas, and water from the ground. But this situation simulates what we are expecting to happen in the future to other low-lying coastal areas with accelerated sea-level rise.

So, the battlegrounds here are very closely drawn.

Let me say a few things about our beaches.

One thing that happens—and I will not go through all of the mathematics and diagrams—is that as the sea level rises, our beaches erode naturally. As I alluded to earlier, as sea levels rose 300 feet in the last 15,000 years, the shorelines retreated 100 miles ilandward.

As the diagram illustrated, sand from the beach is transported offshore to balance things off as sea level rises. There is a natural equilibrium to beaches which must be maintained in concert with a particular water level..

As the sea levels come up one foot, we can expect beach erosion on the order of a couple of hundred feet in many areas. I have some estimates here from various parts of the country.

As you can see, Florida's beach would retreat several hundred feet, with a one foot rise in sea level. In Louisiana, it is several miles of retreat, with even a one foot rise in sea level.

Along the mid-Atlantic coast, the retreat amounts to about 100 feet. This is still very significant as many buildings are built right on the edge of the sea today.

Let me illustrate the present predicament along the east and Gulf coasts, considering there have been a one foot rise in sea level change during the past 100 years.

This is a large tree stump which is now on the beach at Wallops Island, Virginia. There are new facilities being built here and the beach is eroding about 10 feet per year.

Here is a lighthouse that is in danger because of erosion. I think most of you have heard about Cape Hatteras and the problem there.

This shows people living on the edge in Massachusetts. I did some consulting for this person and suggested that they abandon the house—obviously.

She was reluctant to move, however.

I should say that a new public law which passed this year, is going to help her out, because her house is "in danger of imminent collapse." This person can now get some help in moving the house back, rather than collecting the flood insurance when the thing falls over the cliff.

Senator GORE. How much did you get paid for that advice?

Dr. LEATHERMAN. Not enough.

She was a widow of a minister, and, therefore, she didn't have very much money. So it was more of a pro bono case than anything else.

This is another house on the edge of a cliff. This has also been the experience in the Great Lakes (where water levels have changed greatly but are not related to sea level) and have caused this type of predicament. So we can use the high lake levels in the Great Lakes as a natural laboratory to simulate what we are going to find happening along the rest of the United States coastline as sea levels come up.

This house on Fire Island, NY is just about near its end. Examination of old maps and charts show that there were originally two rows of sand dunes in front of this house when it was initially built at the turn of the century.

Obviously things are changing.

More recently, this house in Southampton was built at a cost of several million dollars. It was built right on the edge; and, indeed, he has a very good view of the ocean (indicating).

This is from the cover issue of "Time" magazine last summer, and it shows an area in Westhampton Beach with severe beach erosion problems.

So what is our response to beach erosion? One approach is to retreat from the coast. Some people call it abandonment. In some areas that is the logical alternative, say for the Outer Banks of North Carolina. Most

of those areas are developed little and buildings can be moved back. That is probably the best strategy.

In other areas, sea walls have been emplaced. This is the Galveston island seawall, which has saved the city of Galveston several times from hurricanes. But in the process, of course, there is no beach left. Many people would not want to be living in an area without a beach, which is often the number one attraction in a coastal resort area.

The final option, of course, is beach nourishment. This is the famous Miami Beach nourishment project, completed at the cost of $65 million in 1980. The beach which was increased by 300 feet. The then-mayor of Miami Beach said it was a waterfront slum before beach replenishment and international tourism had plummeted. So a new beach was emplaced, and the tourists are back. Again, I must reiterate that this is not inexpensive, $65 million to move sand grains from Point A to Point B. This beach rebuilding by pumping sand from offshore is occurring today at Ocean City, MD.

So, thank you very much.

[The statement follows:]

STATEMENT OF DR. STEPHEN P. LEATHERMAN, DIRECTOR, LABORATORY FOR COASTAL RESEARCH, UNIVERSITY OF MARYLAND

INTRODUCTION

A significant portion of the world's population lives within the coastal zone, with many buildings and facilities built at elevations less than 10 feet above mean high tide level along the shoreline. Presently, many of these structures are not adequately above existing water levels or located far enough landward to adequately ensure their survival and safety of the people during major storm activity. This hazard has grown increasingly apparent and serious along much of the U.S. East and Gulf coasts, particularly the highly urbanized sandy barriers, as relative sea levels have risen during the twentieth century.

The general effect of sea level rise on coastal lowlands is to induce landward retreat—beaches erode and marshes are lost. Most sandy shorelines worldwide have experienced recession during the past century. Such has also been the case along the U.S. coasts; historical data indicate that about 90 percent of our sandy beaches are eroding. Accelerated sea level rise due to greenhouse-induced global warming will only increase erosion rates and exacerbate the present shoreline dilemma. Also, coastal marshalands will be lost at every-increasing rates, with the nation's marshes perhaps disappearing at the high rates of loss presently experienced in Louisiana.

COASTAL WETLANDS

Coastal wetlands account for much of the land less than 5 feet above sea level. These extensive marshes, swamps, and mangrove forests fringe most of the U.S. coastline, particularly along the Atlantic and Gulf coasts. These areas are vital to our fisheries industry, maintenance of water quality, and are important in coastal recreation.

Salt marshes exist in a delicate balance with water levels. With gradual sea level rise (due to local subsidence or worldwide changes), marshes can generally keep pace by trapping sediments in the water column and through accumulation of their own organic material (dead stems and leaves). However, an imbalance can develop if sea levels rise significantly faster than deposition on the marsh surface, eventually resulting in waterlogging and loss.

Land losses in most wetlands result from a combination of mechanisms, with shoreline erosion at the seaward edge of the marsh being the most obvious process. This factor can be expected to accelerate with increased water levels, but shoreline erosion probably accounts for only a few percent of all marsh losses annually. Most marshes will be long since submerged before extensive shoreline erosion occurs.

A more probable catastrophe mechanism of march loss with a significant increase in sea levels (e.g., several feet) will be formation of extensive interior marsh ponds. These shallow-water bodies enlarge and coalesce at the expanse of marsh vegetation in reponse to rapid coastal submergence. The magnitude of such losses can be quite extensive as shown by studies at the Blackwater Wildlife Refuge in Maryland, where over one-third of the total marsh area (about 5,000 acres) was lost between 1938 and 1979 by this process. These marshes are being lost because sea levels outpace the ability of the marsh to maintain elevation, ultimately resulting in root death of the marsh plants.

BEACHES AND COASTAL BARRIERS

Most sandy shorelines worldwide have retreated during the past century. Progradation has been restricted to coastal areas where excess sediment is supplied by river sources or where the land is being elevated due to uplift in some northern regions (e.g., Maine). Human interference cannot be considered a primary casue of erosion since retreat also occurs on sparsely populated and little-developed sandy coasts. Such recession could result from an increase in storminess, but this trend would have to be almost worldwide to account for erosion on geographically dispersed sandy shorelines. Therefore, in view of the demonstrated general relative rise of sea level along the U.S. shoreline, the link between shore retreat and sea level rise is based on more than circumstantial evidence; it can be stated that the relationship is causal in nature.

In some areas, it is clear that human actions have caused substantial erosional pressures. Undoubtedly the principal problem has been construction of jettied inlets and deepening of channel entrances for navigation. Along shorelines with high rates of longshore sediment transport, these constructed features trap sediment at the updrift jetty and, if material dredged from the navigation channel is not placed on the

downdrift beaches, cause an amount of downdrift erosion equal to the reduction in transport. At some Florida entrances, tens of millions of cubic yards of dredged material have been dumped offshore and thus are permanently removed from the beach. This has resulted in very high erosion concentrated downdrift of tidal inlet entrances.

Historical data (maps and aerial photographs) can be used to determine rates of shoreline change. Over one hundred years of record are available for the U.S. coasts from the National Ocean Service of the National Oceanic and Atmospheric Administration (NOAA). This accurate informational base has been utilized for large stretches of the coastline (including much of the U.S. Atlantic and parts of the Gulf and Pacific coasts) to determine historical rates of beach erosion and barrier recession.

The national (unweighted) average rate of shoreline recession is slightly more than one foot per year. Along the Atlantic coast, beach erosion has historically amounted to about two to three feet per year, with the Virginia barrier islands exhibiting the highest rates of erosion (tens of feet per year). The Gulf coast states are distinguished by having the highest average erosion rate in the nation (over five feet per year). While parts of the Florida panhandle are fairly stable or only slightly eroding, the deltaic coast of Louisiana is by fare the most dynamic (15 feet/year of erosion on average). The Pacific coast is essentially stable on average, considering the fact that more than half of the shore is hard rock. Locally, there are severe erosion problems (e.g., Oceanside, CA), and winter storms have caused dramatic losses of very valuable property in recent years where the beaches are already quite narrow (e.g., Malibu during the 1981–82 storm season).

A number of techniques have been developed to project shoreline retreat due to sea level rise (see 1987 National Academy of Sciences report). Accelerated sea level rise due to the greenhouse effect will increase the erosion rate and cause stable beaches to begin eroding. Based upon the projected rates of sea level rise, it is estimated that sandy beaches will erode at two to five times their current rate. This portends major problems for low-lying areas, such as coastal Louisiana, and increased problems at such beach resorts as Ocean City, Maryland, where the historical rate of beach erosion has amounted to two feet per year. Many of the urbanized beaches along the East and Gulf coast barrier chain are already critically narrow and in need of beach nourishment to protect the existing buildings and infastructure. Such is the case at Ocean City, Maryland, where a $30 million beach fill project is scheduled to begin next spring. Elsewhere, many other recreational beaches have been nourished (e.g., Atlantic City, NJ; Myrtle Beach, SC; Miami Beach, FL). The expected lifetime of nourished beaches will be greatly foreshortened by acclerated sea level rise, increasing the frequency and magnitude and hence the cost of such activities.

RESPONSES

There are three general responses to accelerated shoreline erosion: (1) retreat from the shore, (2) armor the coast, or (3) nourish the beach. The choice of a response strategy will depend upon a number of factors, including socioeconomic and environmental conditions. The decisions reached will likely be site-specific so that each area/community must be evaluated separately.

For highly urbanized areas, such as Miami Beach, FL or Ocean City, MD, the abandonment option is not realistic. The value of such beachfront property with high density and high-rise structures often approaches $100 million per mile, making beach restoration the most attractive alternative. Elsewhere, sea walls have been constructed to stabilize the shore and protect coastal communities from the ravages of major hurricanes (e.g., Galveston, TX). For eroding shorelines that are less developed, the decision becomes more difficult. Therefore, the costs and benefits of protection must be weighted against those of retreating from the shoreline.

CONCLUSIONS

1. Worldwide sea levels have risen about one-half foot in the past century. The rates have been variable along the U.S. coasts for a number of reasons, but have amounted to one foot per hundred years along the mid-Atlatic coast. The rate of relative sea level rise in coastal Louisiana is about 10 times greater than the worldwide average due to subsidence.

2. The general response of low-lying lands to sea-level rise is retreat via beach erosion and wetlands loss. Already extensive coastal marshes are being lost in Louisiana, and it is expected that many of the barrier systems on this deltaic coast will break-up and disappear in the next half century. Extensive salt marsh loss has also

been reported in the Maryland Chesapeake Bay (over 5,000 acres lost at Blackwater marsh, mostly occurring during the past 40 years).

3. The prospect for coastal wetlands is bleak in light of existing conditions and projected changes (e.g., greenhouse effect). Marshes in Louisiana, for example, are not able to keep pace with relative sea level rise, and are presently being drowned in place. A rapidly subsiding land surface or accelerated sea level rise can yield similar results. There will be substantial losses of coastal marshes in the future.

4. Approximately 90 percent of the nation's sandy beaches are experiencing erosion. Historical shoreline studies indicate a wide range in erosion rates (essentially stable to over 30 feet per year). The Atlantic coast average is between two and three feet of beach erosion per year, the Gulf coast exceeds five feet per year, and the Pacific coast is stable on average (much of the shore is hard rock).

5. Accelerated sea level rise due to the greenhouse effect will at least double and perhaps quadruple erosion rates, depending upon which rise rate is actually realized.

6. There are three general categories of human response to shoreline recession: (1) retreat from the shore, (2) armor the coast, (3) nourish the beach. The proper response will be site-specific on a community or coastal sector basis due to large differences in environmental and socioeconomic factors. The abandonment alternative is not realistic for highly urbanized beaches, like Miami Beach, FL and Atlantic City, NJ. For less developed areas along eroding shorelines, the decision becomes more difficult. Therefore, the costs and benefits of stabilization vs. retreat must be carefully considered as the cost in either case is likely to be quite high.

7. The apparent national desire to live in the coastal zone has long term and expensive consequences. The Federally-insured flood program is already burdened with billions of dollars of insured properties close to the water's edge. Accelerated sea level rise due to the greenhouse effect will further jeopardize these vulnerable properties, eventually resulting in massive destruction (without ameliorating action) during future major storms at great expense to the American taxpayer.

The CHAIRMAN. Thank you very much.

Next we have Dr. Hall.

STATEMENT OF J. MICHAEL HALL, DIRECTOR, OFFICE OF CLIMATIC AND ATMOSPHERIC RESEARCH, OFFICE OF OCEANIC AND ATMOSPHERIC RESEARCH, NOAA, DEPARTMENT OF COMMERCE

Dr. HALL. Thank you, Mr. Chairman.

It is a pleasure to be here this morning.

My purpose this morning is to advance the arguments that are being put before you, but, in particular, to underscore the role of the ocean in determining climate change and to tell you something about the present state of knowledge.

In passing, I will mention one or two programs from which we have learned some vital lessons about the ocean's role and, in particular, how to study it.

We have known intuitively, for many decades, I would say, that the ocean was a key determinant in climate and in climate change. But in the last decade, we have learned from mounting theoretical evidence, from observational evidence, and from some particular research programs that the ocean indeed plays a critical role: We need not speculate on its importance. As research programs are implemented, we need not fear that the ocean side of the problem will receive resources as a minor adjunct to atmospheric studies or other studies that appear to be of more importance.

I would like to cite a couple of examples of how we have learned this.

The first of these comes from more than a decade of watching oceanographic variability in the tropics, processes that are known to you as El Nino. They represent a class of variations in ocean warming in the tropics. El Nino is the strongest of them.

For some time, as we watched the ocean varying in gradual ways from year to year, we began to perceive that the atmosphere was varying in comparable ways.

What we have learned as a result of a focused research program on the ocean and atmospheric phenomenon associated with El Nino is that the atmosphere and the ocean act in concert to determine climate change.

The Tropical Oceans and Global Atmosphere (TOGA) program, the one I just mentioned has established that, even for year to year variability, the atmosphere and ocean are, if you will, full partners in determining change, and we have begun to learn how to study their effects.

We have seen that the ocean and atmosphere oscillate, they change together. In this particular program, we have seen how a number of nations can work together to solve the problem when the problem is focused and of practical relevance. More than 15 nations are mounting the TOGA program and something on the order of half of those nations are developing countries who are making real contributions to the problem because they, too, perceive an interest in understanding environmental change and doing something about it.

We believe that in the TOGA program we are learning to predict climate change, in part because we are putting an enormous effort in to understanding the oceanic component.

Now, what about change on longer time scales—ozone depletion, carbon dioxide, global warming and so on? What is the ocean doing in this case?

Here the evidence is even more profound. The example I cited, of tropical variability and extra-tropical regional effects, in TOGA, is concerned primarily with the upper ocean and the behavior of part of the atmosphere.

When you look at the longer-term problems, one of the ways to illustrate the effect of the ocean is to examine the numerical models that are being used. You have heard testimony about these models. You have argued, quite correctly, that we have to pay attention to these models, even in present policy determinations.

It is also of merit to look at the models to tell us something specific about oceanic phenomena. We can take them apart for scientific purposes. We can play with the model. We can invent a world without an ocean, for example, or we can invent a world with an ocean that exists, but whose water does not move.

If we do this for an arbitrary quadrupling of CO2—I will cite one typical model result, but it is indeed representative—and if we invent a world that does not allow ocean currents to move around and rearrange

heat what we discover is that the ocean reduces by more than half the effect of temperature increase in the atmosphere that derives from the increased CO2.

Now that is not terribly good news. The example I am citing (of a CO2 quadrupling) predicted changes in excess of 25 degrees Centigrade in the high latitudes. With an ocean present in the model, on the other hand, it predicted increases of 10 to 12 degrees Centigrade of warming in the high latitudes.

The point is that the ocean plays a fundamental role in modulating long-term climate change. There is an important message in this, but the message is compounded by the fact that the role of the ocean itself changes in time.

So, the only way we can attack climate problems effectively in the ocean is to understand the whole ocean, to understand how the ocean rearranges heat in the atmosphere, not just tropical heating affecting climate in North America, but the whole of the Earth's heating. In fact, we have to understand even more.

We have also to understand how the ocean removes from the atmosphere such things as carbon dioxide. As we look at the more slowly varying physical phenomena that the ocean is such a vital part of, problems other than just ocean physics come to play.

I am speaking now of the role of marine biota. Once we consider changes beyond year to year, decades or more, both animal and plant life in the ocean, particularly planktonic life plays a key role. Particular mechanisms that are hypothesized include the effect of upper ocean plankton on the cloudiness of the Earth—long-term cloudiness patterns may change as a result of direct coupling to ocean plankton—and the role that plankton play in the carbon cycle.

These are the kinds of oceanic processes we have to understand.

There is yet another aspect of the ocean that is important here, again, because the plankton organisms are part of the climate problem. Because they are an active participant in a changing climate, past and present, planktonic mechanisms have left a substantial record, the so-called "earth archive," in the sediments of the ocean and in some lake sediments. Examination of this record must also be made a part of the research program as we move forward.

You have heard arguments this morning that we must learn to detect change unequivocally. You have heard that that is a formidable task. It is doubly formidable in the ocean.

You have heard that when we detect change, we must also learn to understand it. Is it natural? Is it man-made? What does it mean for our social institutions?

And you have heard consistent arguments that we must learn to predict this change and that to do that, we have to understand the component parts of the system.

What I want to leave you with this morning is the idea that the ocean, the whole ocean, is very much a part of that puzzle.

Thank you.

[The statement follows:]

STATEMENT OF J. MICHAEL HALL, DIRECTOR, OFFICE OF CLIMATIC AND ATMOSPHERIC RESEARCH, OFFICE OF OCEANIC AND ATMOSPHERIC RESEARCH, NOAA

INTRODUCTION

My name is J. Michael Hall, Director of NOAA's Office of Climatic and Atmospheric Research. My office is responsible for NOAA's program in Climate and Global Change.

It is a distinct pleasure to be here this morning to discuss with you some scientific problems and opportunities of unusual importance to our Nation.

THE PROBLEM

Mankind can no longer be viewed as a passive participant in a largely stable global environment. Human activity has reached the point where it is affecting the Earth system in ways we can just begin to perceive, but do not fully understand. As we begin to examine the effects of human activities on global change, we are inevitably made more aware of the large natural variability in the global system—the degree to which our global environment fluctuates through normal, natural processes—and the problem of discerning between natural and manmade change. Indeed, our global environment has never been as stable as commonly perceived. Changing climate is a fundamental part of the human condition. Many of its rhythms have become major determinants in the workings of our society.

The combined effects of natural and manmade change can have profound economic and social implications for the future. Severe climatic events such as persistent drought as well as longer term issues such as depletion of the Earth's ozone layer and the possibility of greenhouse warming are but a few of the problems that changes in the Earth system may pose for us. Many nations of the world, including the United States, are beginning to address these serious issues. To make wise and enduring decisions in response to global change, we must be able to predict the consequences of our actions. This means we must be able to predict how the global system would evolve without our intervention and how intervention will modify that evolution. The stunning corollary is that the capability to predict how the global climate system will evolve, partly in response to our actions, offers a new and more productive partnership with nature, one in which we cannot only avoid environmental disasters but also reap new benefits. Realizing this potential will be an important milestone in human history. Today we have far too little scientific information to address these problems effectively, but we have an unprecedented opportunity to achieve the necessary insights.

THE CLIMATE SYSTEM AND THE ROLE OF THE OCEAN

I will focus my discussion this morning on the Earth's climate system and the role of ocean processes in climate: the slowly changing behavior in the climate system is the avenue through which we experience many of the more subtle changes in the larger Earth system. The NOAA responsibility in global change lies particularly in climate change and NOAA has significant capabilities in observations, research and predictive modeling that include emphasis on the ocean part of the problem.

The ocean and the atmosphere are the two working fluids that redistribute the solar heat that warms our planet. Each accomplishes about half of the heat transport. The two fluids profoundly affect one another: the atmosphere forces the ocean through surface winds and the ocean in turn drives the atmosphere through heat exchange at the air-sea interface. The energy exchange processes and the dynamical responses of the two fluids are exceedingly variable and are characterized by complex interrelationships on all time and space scales. Ultimately, theoretical models must be created to understand these complex and variable mechanisms, then these models must be carefully compared with natural behavior to assess their validity.

Figure 1 illustrates the role of theoretical models and demonstrates the importance of accurately representing ocean processes in predicting changes in the climate system. The figure comes from an experimental NOAA computer model of the global atmosphere-ocean system. This model was used to provide early insight into the strong regional differences in atmospheric warming due to projected C02 increases. It under-

scores the substantial role of the ocean in modulating climate change. In this result, ocean currents are responsible for reducing by more than half the anticipated atmospheric response to greenhouse warming if there were no currents.

An effective national program in global change must include a strong focus on the ocean's role in climate change on a variety of timescales—from seasons to decades. The program must examine: the role of tropical ocean processes in year-to-year climate variability, particularly the tropical Pacific phenomenon known as the El Nino; the complex and highly variable global mechanisms by which the ocean stores, rearranges and releases heat and key atmospheric constituents such as C02; and of the role of the marine biosphere in affecting physical climate processes, including the role of marine-generated compounds like dimethylsulfide (DMS) in the formation of clouds and the role of ocean productivity in the global carbon cycle.

Our attack on the problem of global environmental change must retain the central theme of Earth system science—the major elements of the Earth system are interconnected and it is the interrelationships among those elements which we must understand in order to project changes with confidence. Ocean processes represent a critical part of the problem. We must steadfastly avoid the temptation to isolate individual elements of the problem, such as a changing atmosphere, and ensure instead a systematic, holistic approach.

THE INFORMATION REQUIREMENT

Climate fluctuations which affect or which impact human activities include (1) year-to-year (interannual) variability, which has profound economic and strategic implications as we adjust (or fail to adjust) to change, and (2) interdecadal or longer time changes, which have imposed limits on human activities throughout history, affecting even the basic stability of social structures. The concept that climate information has major strategic value in the subtle workings of a society, is well illustrated by considering the effects of recent year-to-year variations in North America, changes we know are driven in part by disturbances in tropical Pacific ocean circulation.

In 1982-83 one of the most significant interannual climate fluctuations of the last century took place. This phenomenon, known in the Pacific Ocean as El Nino, has been the subject of intensive scientific study for the last decade. Much is now known about how it works to effect worldwide changes in the Earth's climate that typically last from one to two years. Studies of these phenomena have been conducted through an international research endeavor called the Tropical Oceans and Global Atmosphere (TOGA) Program. Fifteen nations have formally organized, under the World Climate Research Program, to monitor conditions in the oceans and atmosphere during El Ninos, to learn to understand their workings and to develop methods for predicting their global influences. Scientists in TOGA have compiled a detailed description of the 1982-83 event; its effects on precipitation, clouds, worldwide atmospheric circulation patterns, and its phenomenological roots in the tropical Pacific Ocean are all well established. It can be said that, by January 1983, the Earth's climate system had signalled, unmistakably in retrospect, that a major global perturbation in climate was underway. (Much of the evidence at that moment was to be found in the observed characteristics of the tropical Pacific Ocean.) We could not then, and still cannot, say with any certainty what the regional effects of such an impending change will be: learning to anticipate these is precisely the nature of our challenge.

What were we as a society doing at the time of this event? In January 1983, Congress initiated a new program called Payment-in-Kind (PIK) for holding U.S. agricultural land out of production (through subsidies) in order to avoid excessive crop surpluses. The Federal Government assumed that the normal seasonal changes in our agricultural environment for 1983 would largely resemble those of other years and Congress voted 20 billion dollars of PIK subsidies. 1982 and 1983 were not at all like other years. The summer of 1983, in particular, turned out to be a period of serious heat wave and drought for farmers in the American Midwest. Crop surpluses were destined not to be a problem that year. A reliable prediction six to eight months in advance could have affected a multi-billion dollar agricultural decision over one of the most important sectors of our national economy.

The purpose of research programs such as TOGA is to learn how El Nino and related phenomena are related to mid-latitude regional problems such as the 1983 drought; predicting such effects is the goal of these programs and we are making

steady progress. The El Nino induced changes of 1983 cannot be said to be directly responsible for the summer drought. I wish it were that simple, but it is not. We believe that a large part of year-to-year variability, like that observed in 1983 in the Midwest, is related to variations in tropical heating (such as El Nino), but we cannot yet relate the two in any simple way. The point I want to emphasize is that the relationships between global climate changes and their regional social consequences are yielding to concerted study—the complex relationships can be unraveled and new understanding used to reduce impacts. The importance of these emerging insights to our social institutions is so great that we must make the necessary effort.

This and numerous other examples suggest that climate information is of profound value, that policy decisions can readily be tied to scientific information when it is available and of sufficient quality, and that the prospects are good for major advances in the necessary understanding. If there is a single key to the application of tomorrow's climate information to practical problems, that key is prediction based on sound scientific understanding. Scientists throughout the world have devised a new and effective way to fulfill this requirement by viewing the Earth as a single system, in which climate is one important element. The emerging national program in global change is strong evidence that scientists are poised for a broad attack on the research problems inherent in this undertaking.

No single agency alone has the capability or resources to address the problems of global environmental change. In the United States, the involved Federal agencies recognize this fact and, through the Committee on Earth Sciences, are working closely together to define the objectives and research priorities of a national program and, perhaps most importantly, to orchestrate a well-coordinated effort which takes advantage of each agency's unique capabilities, programs, and plans.

CONCLUSIONS

We have seen that climate change can have profound implications for society. We are just beginning to learn the extent, quantitatively, to which climate information can pay practical dividends. There is a vital need to improve our knowledge base. NOAA continues to pursue the objective of predicting the behavior of the Earth system, particularly climate change on societally relevant timescales. Much of our work is concerned with the changing atmosphere, but the behavior of the world,s oceans and their biological subsystems, is an inescapable part of the puzzle. The problem is scientifically tractable; we have research strategies and plans in place for implementation of effective programs. In concert with other Federal agencies and the national and international scientific communities, NOAA will focus its resources on bringing all of the necessary elements together into a working information service—the long-term knowledge base for U.S. decisions on our changing global environment.

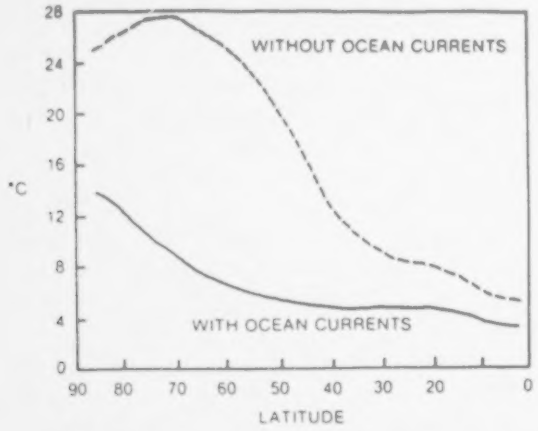

Figure 1. Simulated changes in atmospheric temperature due to a fourfold increase in carbon dioxide (Manabe, et al).

The CHAIRMAN. Dr. Hall, we also heard that your agency, NOAA, needed to readjust its emphasis and its capabilities; that rather than just coastal zone management and the weather predictions, we ought to be getting more deeply into the long-range basic science of global change.

What is your comment?

Dr. HALL. I think I would agree basically with what Dr. Bretherton outlined.

The constraints of resources, but also constraints of what we know how to do in our science, have led us to a point where weather and weather prediction are a very dominant part of our mission.

Sociological problems and economic problems have led us to concerns of coastal zone management, and so on.

I would like to say that because the science is developing the way it is (I believe Dr. Bretherton correctly captured the unique responsibility that NOAA has), we in the agency have been, for some time now, taking a very hard look at how we can achieve the future posture that Dr. Bretherton described, and, indeed, see the arguments very much the way he made them.

The CHAIRMAN. Dr. Watson, you said we must separate the science from the policy itself. Where are the conflicts that you see now in the administration here of our study and in the handling of global change, and our research, our science and in our policy? Where are the conflicts as they now exist, as you see them?

Dr. WATSON. I think at this moment in time they are fairly reasonable. At this moment in time, the science agencies, working with the National Academy of Sciences, try to put forward a science program. There is cognizance of the needs of the policy agencies, such as EPA, but we are not directed by an agency such as EPA.

What I am stressing here is, I think, a situation that we want to maintain for the future. I think it is very important that the science agencies have a very strong dialogue with policy-makers both on the Hill and in the administration so that we understand the types of issues that you need answers for.

But I believe it is up to the scientific agencies and the National Academy of Sciences to put that integrated science program forward. It needs to be broad. For example, the Antarctic ozone issue came upon us very quickly.

But once we recognized there was a problem in Antarctica, the science agencies—NSF, NASA, and NOAA—basically put two programs forward within less than two years. We now have a very good understanding of why the Antarctic ozone hole exists.

This really was because of a commitment of ten or more years of dedicated research in each of those three agencies—not driven by policy, but basically driven by the need to understand the system.

The CHAIRMAN. The administration of the policy, of course, I guess is in the Environmental Protection Agency. The basic science, then, is in the National Science Foundation and in NOAA and NASA, as you see it?

Dr. WATSON. Yes. Correct.

The CHAIRMAN. What about the bill. Does any one of the four of you want to criticize it? Is it inadequate? Are we headed in the wrong direction? Is it unnecessary? Is there any particular criticism of it?

Dr. Watson, what do you think?

Dr. WATSON. I will give a personal comment, not necessarily one shared by NASA because we have not had time to look at it.

I believe the bill correctly recognizes the very strong need for more than one agency to look at this issue. It recognizes that NASA, NOAA, NSF and USGS have complementary roles, that we have a strong role, and that we must work together.

So, I think from the standpoint of recognizing that four agencies have important roles is very important. It potentially skirts the issue of what to do with the National Climate Program Office. I think that is one issue that has to be looked at in some detail in the future.

At first glance, it seems to be a step definitely in the right direction.

The CHAIRMAN. Senator Gore.

Senator GORE. Thank you, Mr. Chairman.

Dr. Watson, I certainly appreciate the fine work that you have done on the ozone depletion issue. We have had a chance to work together in the past.

I apologize for interrupting you at the beginning of your testimony. Indeed, the Montreal Protocol does call for a 50 percent reduction; but it allows for a steady increase up until the year 1999, and if you measure from—you don't disagree with that, do you?

Dr. WATSON. No. I agree completely.

Senator GORE. If you measure from right now, all it calls for is a 35 percent decrease.

You said that we would have to have a decrease of 85 to 90 percent in order to stabilize the rate of damage. Is that accurate?

Dr. WATSON. If one had an 85 percent cutback in the emission of the fluorocarbons today, all fluorocarbons, not just the fully halogenated ones, but the ones not covered under Montreal, like methylchloroform, you would stabilize the chlorine level at today's level.

But what that would mean is chlorine would remain at about three parts per billion today in the Earth's atmosphere. That clearly won't get rid of the Antarctic ozone hole which we have today.

So, if one wanted to go back to a position with no Antarctic ozone hole, I personally believe we must reduce the levels of chlorine in the Earth's atmosphere to the order of two parts per billion. That will require greater than an 85 percent cutback in the emissions not only of the fully halogenated CFCs but other CFCs.

Senator GORE. Okay. Just so we have a clear picture of what has been accomplished—and it is a substantial accomplishment. I don't wish to denigrate it. But it is pitiful in the longer view because we are not even stabilizing the rate of damage.

We are sanctioning a continued acceleration in the rate at which the stratospheric ozone layer is being destroyed.

You mentioned, Dr. Hall, the importance of plankton and the ocean biota.

What is the status of the preliminary work, Dr. Watson, on the effect of increased UV radiation on the ocean biota?

This is for Dr. Watson or Dr. Hall. Does either of you know that?

Dr. HALL. Dr. Watson is probably better able to answer than I am.

Dr. WATSON. Unfortunately, our knowledge is extremely rudimentary. All that I can say is that more UV cannot be anything but adverse to the plight of plankton in the southern oceans. But we cannot quantify it at the moment.

Senator GORE. All right.

Now, these two issues are sometimes confused, the destruction of the ozone layer and the greenhouse effect, or the global climate change. They are very different. But CFCs are principal villains in both problems—correct?

Nobody disagrees with that who is on the panel, correct?

Dr. WATSON. Correct.

Dr. HALL. Yes.

Dr. LEATHERMAN. [Nods affirmatively]

Dr. ROSENBERG. [Nods affirmatively]

Senator GORE. All right. And so, we are continuing to produce them. That is pretty crazy, in my view.

Now, Dr. Watson, I asked NASA—I didn't really give you enough time to do it, but I want to know whether you have a response. NASA produced a film based on their computer model, which was shown at the hearing before this Committee one year ago, which graphically illustrates the changes in temperature around the world. I asked if you could change the variables in the model and graphically illustrate for us the changes in moisture distribution, as predicted by the computer model, and bearing in mind that the internal uncertainties in that are greater than with temperature distribution.

Have you had a chance to do that?

Dr. WATSON. Actually, while I have testified before you a couple of times, that was probably Jim Hansen that you asked to do that. I have only ever shown you films of ozone. I think at the same hearing Jim Hansen also testified. I don't know whether he has done the study.

Senator GORE. Oh, I didn't ask you. I asked NASA.

Dr. WATSON. Yes. Jim Hansen may have done it. But we can find that information for you.[1]

Senator GORE. All right.

Dr. Rosenberg, just very briefly, I wanted again to say that I think the winners and losers argument is one that is not helpful to make. I respect your right to make it. It was a very minor point of your testimony and I appreciate your testimony.

But there is in my view a tendency on the part of some to pose what I believe is a false choice between adaptation and corrective action.

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[1] See p. 81.

It is true, as you say, that there are changes already in the mill and some adaptation will be essential. But, in my view, corrective action is even more essential because, unless we have it, the changes will increase by several orders of magnitude, and the adaptation will become increasingly difficult.

Indeed, as was pointed out in Toronto—and I will refer to it only one more time—the changes, the harmful changes on global civilization are predicted to be second only to those associated with global nuclear war. I think we really have to change the way we look at this whole problem.

I am prepared to move on to finish up, but if you want to respond, please do.

Dr. ROSENBERG. I would like to do so, Senator.

I agree that corrective action now is the logical step. However, some change is coming, and I think it would be irresponsible to ignore those changes and be unprepared for them when they come.

Senator GORE. Yes, I agree.

Dr. ROSENBERG. But I think not knowing what changes are coming complicates the picture considerably, and, therefore, we should be doing everything possible to reduce our vulnerability to weather and weather extremes and fluctuations as they are today and as they may be exacerbated in the future.

This, I think, is the nature of the policy that I would put forward.

Senator GORE. I have far less disagreement than I thought I would have when you started. I appreciate what you are saying. Just very briefly, you say there has been an increase of about 6 inches, or half a foot, in sea level in this century.

Dr. LEATHERMAN. Yes. That would be the estimate for the global sea level rise. To that you have to add the local or regional components.

Senator GORE. Yes, I understand—a global rise of six inches, due to the melting of glacial ice and thermal expansion of the oceans?

Dr. LEATHERMAN. That's correct.

Senator GORE. Now, when we talk about the world weather system and distribution of moisture, we are talking about the possibility of sudden changes in equilibrium and not necessarily gradual change. Where we discuss sea level increases, we are, in fact, talking about steady, gradual change——

Dr. LEATHERMAN. Yes, Senator—much more steady than the climate record. That's right.

Senator GORE. —until we reach the point where the West Antarctic Ice Shelf is affected. Correct?

Dr. LEATHERMAN. That's correct. If that occurs, then that would be much more drastic and produce tremendous rises. I don't think anybody has even factored that into their calculation.

Senator GORE. Well, some people have.

Dr. LEATHERMAN. Some people have, but not in a detailed fashion.

Senator GORE. The way it was explained to me is if you have a glass of water and the ice cube is floating and melts slowly, the water level does not increase. But if you have a stack of ice cubes and the top one

is not being supported in the water, and it melts, then it overflows. The West Antarctic Ice Shelf, pinned up on islands——

Dr. LEATHERMAN. That's correct.

Senator GORE.——would, if dislodged by melting, suddenly increase the sea levels by, I believe, four to five feet. Does anybody know the number?

Dr. LEATHERMAN. I think it would be more like 10 to 20 feet.

Senator GORE. All right.

Now, finally, Dr. Hall, back to you.

The oceans warm more slowly than the land mass, correct?

Dr. HALL. Yes.

Senator GORE. Is that a fundamental cause of certain changes in the computer models?

Dr. HALL. In essence, yes. The heat capacity of the ocean and the motion of the ocean, if you will, combined, are really the principal characteristic that determines their effect in models. Obviously, there is a great deal more to it. But, in overview, that is the mechanism.

Senator GORE. All right.

Now, there are some uncertainties with respect to the cloud system, which we are not even close to resolving, and there is a major uncertainty with respect to the ability of the oceans to absorb CO2.

Now, the last time I revisited this question, it was up in the air, but the scientific majority was trending decisively toward the view that the warming of the oceans will cause not an increased capacity to absorb CO2, but, in fact, the reverse, and cause the oceans to disgorge CO2, thereby creating a multiplier effect and causing a significant increase in the rate at which CO2 concentrations increase.

Is that still the trend?

Dr. HALL. Certainly that argument has to be taken into account. It is most accurate to say that the oceans both absorb CO2 regionally and give it up regionally.

One of the effects of El Nino variations is a major change in the amount of CO2 exchanged between the atmosphere and the ocean in the Pacific.

The difficulties arise from the fact that those mechanisms, particularly uptake at high latitudes in the world's oceans, are very regional and very intermittent. There is an increasing amount of evidence, for example, that northern latitude uptake of heat and gases can change abruptly and radically, as a result of fundamental changes in the world's circulation.

I would not say that there is a preponderance of scientific argument one way or the other. But certainly the fact of changes in the ocean's ability absorb up CO2 have to be taken into account. And, as you have heard consistently today, we know far too little about the problem to speak with any confidence.

Senator GORE. But the regional variations are a function of temperature variations, correct?

Dr. HALL. Well, they are a function of both temperature and circulation variations in the ocean. But I don't believe I'd put it that way. They are a function of the circulation of the ocean and the condition of ocean atmosphere exchange in the region where the circulation is capable of removing gases.

Senator GORE. I want to thank all of you and our earlier witnesses as well for your contributions today.

Mr. Chairman, again, thank you for your leadership on the issue.

The CHAIRMAN. We thank you.

We thank each of you on the panel, and our previous witnesses. I am sorry that we have to cut this short, due to another commitment.

The record will stay open for written questions and any further observations that each of you has.

Thank you very much.

The Committee will be in recess.

[Whereupon, at 12:00 noon, the Committee recessed.]

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

STATEMENT OF EDWARD M. DAVIS, PRESIDENT, AMERICAN NUCLEAR ENERGY COUNCIL

This statement is submitted for the record of the Senate Commerce, Science, and Transportation Committee by Edward M. Davis, president of the American Nuclear Energy Council. The Council's membership includes nuclear utility companies, utility service companies, manufacturers and equipment suppliers, architect-engineering firms, DOE contractors, uranium producers as well as other fuel cycle and waste management organizations.

The Commerce Committee is to be congratulated for holding hearings on ways to improve the coordination of national research on the global warming trend. Most of such research is being directed to increasing the scientific understanding of this phenomena—but it must do more. National research should also be directed to developing necessary mitigation measures. It is the position of the nuclear energy industry that such mitigation measures should include a revitalized nuclear energy option. Essential to revitalizing the nuclear energy option are several congressional actions: a reasonable and efficient process for licensing nuclear energy plants; implementation of legislation that resolves the issue of nuclear waste disposal; and a continued federal commitment to developing advanced reactor technologies.

Albert Einstein once said, "I never think of the future. It comes soon enough." In terms of climate change and meeting electric needs, the future does come soon enough—often sooner than we're prepared for. But America must think about the future now and begin developing and implementing the national policies that are necessary to address these problems. Finding solutions to the global warming trend will require the kind of foresight that is the foundation of this hearing.

Just as the changes now affecting the global climate have come about over many years as a byproduct of changes in the culture and industrial infrastructure of nations, it will take years to achieve solutions. The United States will be forced to re-examine its energy policies and adjust its energy mix to retard or stabilize global warming—and, just as importantly, to maintain economic and energy security. This statement does not reflect an expert's knowledge of the global warming trend. Neither does it advocate a national energy policy that abandons the use of any fuel source in favor of another, because the widest possible range of energy options must be used. Any combustion of fossil fuels contributes to the greenhouse effect, but the use of fossil fuels cannot be avoided in the many activities of an industrialized nation. For example, they are essential to transportation and heating. There is, however, one area in which the United States does have an established choice, and that is in the area of electricity generation—and that choice is nuclear energy.

The United States must have a balanced national energy policy—one that draws on a variety of energy sources, particularly nuclear energy, which must be revitalized in order to alleviate the greenhouse effect and to meet our growing demand for electricity. The need for this type of policy will require groups that have opposed nuclear energy to reconsider their opposition in light of this environmental problem. No single energy source created the greenhouse effect, and research efforts must not dismiss any single source if the nation is to solve the problem and maintain our standard of living.

Nuclear energy is a mature, proven, successful technology that meets America's growing electricity needs without contributing to the greenhouse effect. Today, 109 operable nuclear reactors provide almost 20 percent of the nation.s electricity. Since 1973 an investment of approximately $130 billion in these facilities has paid off handsomely by displacing about 3.5 billion barrels of imported oil that would have exacerbated the greenhouse effect. These benefits will continue in the future because these plants have generated only a small percentage of the total amount of electricity they will produce in their service lifetimes.

Nuclear energy is an environmentally clean source of electricity. Unlike fossil fuels, nuclear energy generates no carbon dioxide which has been identified as a major cause of the greenhouse effect.

Fortunately, the environmental advantages of nuclear energy are becoming more widely acknowledged and appreciated. The greenhouse effect is causing one-time opponents of nuclear energy to thoughtfully ask themselves if there is a future for this energy source—and, increasingly, the answer is "yes." In the March 88 issue of NATURE magazine, the editors argue that anti-nuclear environmental groups may "find themselves differently impelled if it becomes clear that the only economically feasible way of mitigating the damage that might be done by carbon dioxide is to moderate the use of fossil fuel." The editors predict that international negotiations to achieve this action will be necessary, and that "even the most reluctant communities will begin building nuclear power stations again."

But environmental support for clean nuclear energy existed long before the greenhouse effect became front-page news. Few people may remember that the California Sierra Club, and its most well-known board member, Ansel Adams, the noted nature photographer and naturalist, advocated nuclear energy as an ecologically superior energy alternative. If he were living today, Ansel Adams would likely see the greenhouse effect as further evidence for fostering the use of nuclear energy.

Today, all Americans must be concerned about the effects of global warming on our environment and on our society. And all Americans—including nuclear energy's opponents—must be open to considering every energy source as a valuable component of a balanced national energy policy that is ecologically and economically sound. Today, nuclear energy is no longer an option, it is an imperative—in light of the greenhouse effect, the rising level of oil imports and the increasing demand for electricity.

At the same time scientists are researching the greenhouse effect and identifying solutions to alleviating this trend, the nation's demand for electricity continues to grow. Consider these facts:

Since 1973, the Gross National Product has grown by 38 percent, while electricity use has grown by 43 percent. Clearly, economic growth requires a growing supply of electricity.

Since the economy emerged from recession in 1982, electric sales growth has averaged 3.3 percent a year. In 1987 alone, electricity sales increased 4.5 percent—more than double the estimate of U.S. Department of Energy.

The reality of this growth in electricity demand is staggering. The Department of Energy reports that the United States faces a gap of 100 gigawatts between our planned capacity and projected electric demand by the year 2000. To illustrate the magnitude of this shortfall, 100 gigawatts is more electricity than what is now generated by all of the nuclear plants in the nation.

The simple fact is that the American economy, like the economies of all industrialized nations, is steadily becoming more electricity-intensive. If the nation is to have continued economic growth, additional electrical generating capacity will be needed.

Importing more foreign oil is neither an ecological nor economic answer. Today, the United States imports almost 40 percent of its oil. A 1987 report by Georgetown University's Center for Strategic and International Studies warned that imports could approach the 50-percent level by the mid-1990s, and that half of the projected increases will come from electric utilities. Ironically, utilities' plans for widely available energy alternatives—coal and nuclear—are lower than at any time in the past decade. Further, the low oil prices we currently enjoy cannot be taken for granted in the future. In actuality, today's low prices sow the seeds for high prices tomorrow by encouraging oil use, by shifting demand to overseas sources, and by lulling our consumers, industries and government into false complacency about energy vulnerability. And there is no escaping the fact that oil is a fossil fuel that injects carbon dioxide into the global greenhouse.

Other options exist for alleviating the greenhouse effect but, either together or individually, they are not a panacea for a world that is growing warmer and demanding more electricity. Conservation can help reduce demand, but it cannot offset our entire need in the years ahead. Cutting production of ozone-destroying chlorofluorocarbon gasses can help, but any results will be long-term because these compounds remain in the atmosphere for decades. Preserving the world's tropical forests may help, but will

not alone solve the problem either. Clearly, no single alternative presents a complete solution for alleviating the greenhouse effect. Conservation, renewable energy sources, nuclear energy, as well as appropriate use of fossil fuels must all be included in a balanced energy policy that meets our environmental and economic needs.

THE FUTURE FOR THE NUCLEAR OPTION

A revitalized nuclear energy option that can help to reduce the greenhouse effect and, at the same time, meet the nation's growing demand for electricity, depends on congressional action in three areas.

LICENSING NUCLEAR ENERGY PLANTS

The Atomic Energy Act of 1954 requires that nuclear plants be licensed twice—first for construction and subsequently for operation. This regulatory requirement is inherently flawed because it encourages plant construction before the design is completed. The drawbacks are severe: Major design decisions are made after construction is underway, driving up construction costs. In addition, the Nuclear Regulatory Commission makes safety-related decisions while plants are under construction and orders further design changes, creating further delays and cost escalations. Congress must act at once on legislation providing for standardized designs and establishing a one-step licensing process, in which a complete and pre-approved design is submitted before construction is begun. Such legislation is needed to prevent the higher costs and delays caused by the current licensing process.

NUCLEAR WASTE DISPOSAL

The National Waste Policy Act of 1982 created a legislative solution for safe disposal of waste created by nuclear energy plants. This landmark legislation was reaffirmed in 1987. The United States has the technological means to safely store nuclear waste for the long term, and it is essential that the Department of Energy implement this legislation in an expeditious manner in order to ensure continued development of nuclear energy.

ADVANCED NUCLEAR REACTORS

The greenhouse effect is gaining visibility at a time when the nuclear energy industry is achieving significant advances in operating existing nuclear power plants and developing a new generation of power plants. This vigorous development effort to raise all U.S. nuclear plants to a high level of excellence is a technical prerequisite to reopening the nuclear option, that is, to strengthening confidence in nuclear energy so that there is a national will to move ahead again. Progress in this area is encouraging, and it is not too early to set goals for development of the new reactor systems which will reopen the option and to press on vigorously with those developments. Congress has indicated its commitment to the future of the nuclear option by appropriating funds for research and development of the next generation of nuclear reactors. For Fiscal Year 1989 this amount will be $80.5 million. These funds will help refine technologies that will lead to nuclear energy plants that further enhance the established safety and operating records of existing plants. Over the long term, it is essential that funding for advanced reactor technologies be maintained.

The goal for these new systems is centered around safety. Although from a public safety perspective, the record of the present light-water cooled plants is unmatched--not only avoiding harm to the public but saving many lives each year as compared with other methods of generating electricity--major advances in safety can still be made. The key to this advance in safety is the human factor, so strongly identified by the Kemeny Commission that investigated the Three Mile Island accident as the underlying cause of the accident. The centerpoint of the industry's "drive for excellence" for the country's operating nuclear power plants is the human factor--better training, better procedures, improved-control room interfaces, advanced diagnostic aids, human performance improvement guidelines, and maintenance guidelines.

But significant improvements can be made by introducing additional passive safety features into new designs. Such features reduce reliance on active equipment to respond to emergency conditions, substituting instead additional intrinsic characteristics such as gravity cooling, natural circulation, intrinsic heat sinks, and natural "governors" which cause reaction rates to slow down when temperature or power speeds up.

Each advanced system—the advanced light-water reactor (ALWR), the liquid-metal reactor (LMR), and the high-temperature gas cooled reactor (HTGR)—has incorporated such passive safety features. Taken to their full extent, the end result is that operators need not act in hours but in days to respond to a serious accidental condition such as a loss of cooling or failure of the reactor shutdown systems. This is the ultimate response to the human factors issue which makes the training and other aids easier and surer to implement.

Finally, and equally important to the future of nuclear energy and its contributions to alleviating the greenhouse effect, the American public and the scientific community recognize that this energy source will be a vital contributor to our nation's energy future. A national poll conducted in May found that 81 percent of those surveyed believe that nuclear energy will be important in meeting our electricity needs, and 78 percent believe it is likely that additional nuclear facilities will be required.

Last year, a national sampling of scientists listed in "American Men and Women of Science" revealed that 88 percent believed that nuclear energy will be essential to fulfilling America's demand for electricity in the years ahead. Significantly, this survey—and a second 1987 poll of engineers and scientists selected from the readership of "Scientific American"—found that almost 70 percent of the respondents considered the current generation of U.S. nuclear reactors safe.

The efforts of the Commerce Committee to improve scientific research on and understanding of global warming are to be commended, and the American Nuclear Energy Council appreciates this opportunity to submit the views of the nation's nuclear energy industry. Much remains to be learned and understood about the greenhouse effect and its far-reaching impact on our society. But one message should be clear: Americans cannot cling to the energy patterns, policies and prejudices of the past.

The American public, the scientific community and the nuclear energy industry are ready to move ahead with solutions to stem the greenhouse effect and preserve our economic and energy security. The industry is committed to assuring that nuclear energy will be a safe and economically viable alternative.

National research that leads to the development of a balanced national energy policy that includes an expanded role for environmentally clean nuclear energy is an essential first step in preserving our environment and our standard of living for the next generation of Americans.

NASA
National Aeronautics and
Space Administration
Goddard Space Flight Center

Goddard Institute for Space Studies
2880 Broadway
New York, N.Y. 10025
(212) 678-5500

August 4, 1988

Senator Al Gore
U.S. Senate
Washington, DC 20510

Dear Senator Gore,

Jerry Mande of your staff and Bob Watson of NASA Headquarters have each contacted me with regard to your request for a film to illustrate the possible impact of increasing greenhouse gases on droughts in the United States. This letter is to confirm that we are now working on this task, and to mention briefly principal caveats which should accompany the results.

One point I wish to stress is that climate model simulations of precipitation-related quantities are much more uncertain than temperature projections. Temperature change is a direct effect of the greenhouse warming mechanism, while moisture changes are more indirect, resulting from several different processes which are often competing; some of the key hydrologic processes (e.g., moist convection and evapotranspiration) are simulated very crudely in current models. This does not reduce the importance of hydrologic changes, which undoubtedly will accompany greenhouse warming, but it makes it very difficult to tell people what to expect.

A related point concerns the broad range of results from different models for summer "drying". As shown in the enclosed paper by Kellogg and Zhao, the results range from pervasive, stong drying in Manabe's (GFDL) model to weaker and more mixed changes in our (GISS) model. One result is that a film of GISS results will show mostly fluctuating wet and dry areas, with any long term trends probably difficult to discern.

We recognize the value of visual material illustrating climate change, and we will try to produce something useful for you. We will keep in contact with Jerry Mande regarding our progress.

Sincerely,

James Hansen, Head
Goddard Institute
for Space Studies

cc: R. Watson/NASA HQ

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VA. 22092

OFFICE OF THE DIRECTOR

In Reply Refer To:
WGS-880212
Mail Stop 104

OCT 17 1988

Honorable Ernest F. Hollings
Chairman, Committee on Commerce,
Science, and Transportation
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

The enclosed responds to your letter of August 9, 1988, in which you asked that we answer follow-up questions to the July 13, 1988, hearing before the Senate Commerce Committee.

Thank you for the opportunity to provide this information to you for inclusion in the official hearing record.

Sincerely yours,

Dallas L. Peck
Director

Enclosure

RESPONSE BY DR. DALLAS L. PECK TO QUESTIONS SUBMITTED FOR THE RECORD BY SENATOR ERNEST F. HOLLINGS SENATE COMMERCE COMMITTEE HEARING ON GLOBAL CHANGE RESEARCH

JULY 13, 1988

QUESTION 1. The term "global change" has been used in discussing a large number of environmental problems from acid rain to ozone depletion. It has also been applied to naturally occurring changes such as sea level fluctuations.

a) How would you define global change?

b) Where do we draw the line on the research included? Do we include any research that is in some way related to changes on planet Earth, or do we focus on immediate concerns such as ozone depletion or carbon dioxide?

RESPONSE

1a) Global change is the system of interactions, feedbacks, and changes among the physical, chemical, and biological processes that regulate the total Earth system; the environment that it provides for life; and the manner in which they are influenced by human activity. The word "change" may be misleading because we need to understand the processes involved in change in order to interpret or forecast the course of change; the study of interactive processes provides the fundamental understanding necessary to develop response strategies.

1b) Global change as defined above requires that the Earth be studied as a unified, dynamic system. Dominant changes that affect the environment and the course of life on Earth are natural ones, induced by forces of natural selection, the shifting of winds and rivers, the dynamic processes of the atmosphere and oceans, the contraction and expansion of ice sheets, changes within the solar system, and the drifting of continents. However, we perceive some of the resultant consequences of these major Earth processes through changes in precipitation patterns, carbon dioxide levels, and sea level height to name but a few. Nearly all solar and earth phenomena can be linked to interactive processes; the Global Change Program, however, will focus on those processes that most directly influence the environment.

The Global Change Program is designed to assess the current state of our understanding and identify gaps in that understanding which are the key to the more pressing concerns such as greenhouse gases, ozone and carbon dioxide (CO_2) levels.

QUESTION 2. As chairman of the FCCSET Committee on Earth Sciences (CES), you've had the difficult task of getting almost a dozen agencies to work together on global change research.

a) Based on your experience thus far, what's the verdict? How would you assess your progress toward defining and implementing a comprehensive national program?

b) What have been the biggest challenges in coordinating the various agency research programs?

c) Please comment on the issue of coordinating related agency budget requests. Has the CES addressed this issue? If so, how?

d) Do you think that S. 2614 would make the job of coordinating Federal global change research easier?

RESPONSE

2a) The CES has made significant progress toward the development of a global-change program. At present the Committee is developing decade-scale program goals. We have completed a description of our current programs, and now have an accurate accounting of our current programmatic foundation.

2b) At the outset of our program analysis, we were immediately challenged by the complexity of our task from both an administrative and scientific perspective. In order to understand what initiates changes in climate so as to formulate a policy response strategy requires an understanding of the forcing functions of the system; and predicting the magnitude and timing of the climate change requires an understanding of the climate and planetary response processes. The CES together with the National Academy of Sciences' Committee on Global Change has addressed these issues in an attempt to arrive at a scientific consensus identifying our knowledge base, any gaps in that base, and the programmatic direction for the future. This exercise has presented a major challenge, but one that has been met with coordinated determination and resolve by both Committees.

2c) At present the member agencies have developed a common perception of the overall program needs; each submits their budget requests separately to OMB, OMB evaluates the requests in consultation with CES agency staff. We believe that the development of common goals for the Global Change Program and the definition of complementary roles for the CES agencies will lead to cost efficient, nonduplicative budget requests, even though requests will not be developed collaboratively.

2d) S. 2614 encourages cooperation both within the Federal and non-federal sectors to effectively advance the scientific understanding of global change. Such cooperation and exchange of scientific information is essential if we are to grapple with this complex problem. S. 2614 is consistent with the intentions of the Executive Branch to provide a focus for coordinated planning through FCCSET.

QUESTION 3. The federal government has already made a substantial investment in global change research, spending tens of millions of dollars in this area each year.

a) Looking at the current programs, are there situations in which effort and money have been wasted because of lack of coordination between agencies?

b) We have been collecting environmental and weather data from satellites for many years now. Is that information of use in studying global change? Please explain.

RESPONSE

3a) There has not, to the extent this Committee can perceive, been money wasted on scientific efforts due to lack of coordination. However, it is hoped that through a coordinated effort the overall effectiveness and productivity of the Federal Government's programs which address global change may be enhanced. As an example CES has provided a forum for and is proceeding to establish a mechanism for, data directory exchange which will enhance our information base and eliminate duplication of effort.

3b) Weather satellite data is an important source for environmental information that is incorporated into the General Circulation Models (GCM) used to both model and forecast past, present, and future climatic conditions. For example, the International Satellite Cloud Climatology Project (ISCCP) provides information to us on cloud characteristics,

elevation, and water vapor transport. This type of information cannot be provided from surface-based observations with a sufficient degree of areal coverage required for our models. Projects such as ISCCP need to be converted from research projects to extended monitoring projects with a research component, so that the earth-science community may be assured that data of this type will be available and provide a base of comparison not only for interannual but interdecadal cycles.

QUESTION 4. By all accounts, you've done a superb job as head of the Committee on Earth Science. However, CES seemed to get off to a rather slow start.

a) How do you account for the rather slow progress of CES in the initial months after its formation?

b) What can be done to strengthen the ability of FCCSET and CES to develop a stable and effective program for studying the long-term problem of global change?

RESPONSE

4a) CES, in a unique precedent, was charged with the coordination of all earth-science activities of the Federal agencies. Differences among the agencies with regard to the concept and style of the CES operation required several months following the formation of CES for development of consensus on how CES would function.

4b) The most effective means I know for assuring the success of the global-change program is for the FCCSET and CES to maintain and strengthen our partnership in the administration of this program. The CES agencies, OMB, and the Congress will need to adopt long-term perspectives, particularly with regard to the acquisition and management of environmental data. This will require close cooperation and good communication. The ultimate measure of success will be the demonstration by CES of our ability to function as coordinator and effective manager of earth-science programs.

QUESTION 5. The FY 1989 budget for the Office of Science and Technology Policy (OSTP) will be less than $1.6 million, about a 15% reduction from last year.

a) How will the reduced budget for OSTP affect FCCSET and the Committee on Earth Science?

RESPONSE

5a) At present we anticipate that the 15% reduction in OSTP will have little impact on FCCSET or CES activities. Funding for CES programs originates from within the CES member agencies and CES agencies provide all CES staff support.

QUESTION 6. In order to ensure a coherent, Federal global change research program, S. 2614 would require coordination between NASA, NOAA, NSF, the Geological Survey, the Department of Energy, the Agriculture Department, EPA, and DOD.

a) Have we left anyone out? Are there other agencies that have significant global change research programs that should be included?

RESPONSE

6a) Due to the international nature of the problems which need to be addressed, the Department of State, a member of CES, would be an appropriate member of the Federal global-change program. The State Department's involvement would facilitate the required international exchange of scientific information and development of collaborative research programs with other nations.

The Department of Transportation (DOT) research programs directed toward assessment of the impact of global change on human activities indicates the pertinence of DOT research to the global-change program. Recognition of DOT activities has prompted the Chairman of FCCSET to invite that agency to join the CES.

The potential for inclusion of other bureaus of the Department of Interior in addition to the Geological Survey is also being explored in relation to their activities in global-change research.

QUESTION 7. We hear that greenhouse warming will increase the earth's mean temperature by five degrees by the year 2050. As a geologist, you're trained to think on timescales much longer than typical Congressional timescales. Thus, you can give us some insight into how the predicted changes in the global environment compare to such changes in the past. We know that less than 15,000 years ago the earth was colder than today and Boston, Chicago, Detroit, and Seattle were covered by a mile-thick ice sheet. On the other hand, 70 million years ago the earth was so warm that palm trees and dinosaurs lived on the North Slope of Alaska.

a) How do geological changes in climate compare with the changes that might be caused by greenhouse gases?

b) How quickly did these past changes in climate occur?

RESPONSE

7a) Past geologic changes in climate as revealed through the interpretation of geologic records demonstrates an enormous amount of variation in the Earth's temperature over geologic time. The magnitude of climatic changes in the past has been greater than changes expected to occur by the year 2050 caused by greenhouse gases. Caution must be observed however; 2.8 million years ago the Earth was 5 degrees warmer than present and the concentration of carbon dioxide in the atmosphere also was higher. If similar conditions were to reappear and we superimpose upon this scenario additional anthropogenic carbon dioxide, the variations in the Earth's temperature could exceed that which is anticipated due to greenhouse gases alone. Currently concentrations of greenhouse gases in the atmosphere are increasing at unprecedented rates; the climatic consequences of such rapid changes are uncertain.

7b) Climate is dynamic, not static, and constantly changes by different amounts over a range of time-scales. Changes similar in magnitude to a global 5 degree centigrade warming have occurred naturally over time-scales of one to several thousands of years. Smaller, but still significant changes, have been demonstrated to occur naturally over time-scales of decades.

Analysis of impurities and gases trapped in natural ice provides a method for reconstructing the history of atmospheric composition before the period of direct measurement and offers the possibility of extending the historical atmospheric record to at least 100,000 years before present. Ice cores have revealed significant climatic variation accompanied by simultaneous correlated rapid CO_2 variations. Similar information concerning the past climatic environment can be obtained through analysis of sedimentary materials from oceans and lakes.

A recent study of depositional patterns for sediment and biological material within the bottom sediments of Elk Lake, Minnesota, conducted by the U.S. Geological Survey, provides one of the best decadal records of climate change extending 10,400 years before present. Between 8,500 and 4,000 years ago,

precipitation patterns significantly changed three different times. There were two distinct dry periods separated by a moist interval that lasted for 600 years. The transition between intervals was rapid and calculated to have occurred over a period of less than 50 years in each of three cases. Due to the unique qualities of the Elk Lake record, we were given a rare opportunity to study climatic changes over decadal periods. This record indicates that although certain climatic patterns may persist for periods of centuries to thousands of years, the transition from one climatic pattern to the next may occur within the period of a few decades. The prospect of rapid change, with potential human consequences, is a primary motivation for improving our knowledge of global change.

NASA

National Aeronautics and Space Administration

Washington, D.C. 20546

XC:MDD:X88-00325f

OCT 20 1988

Honorable Ernest F. Hollings
Chairman
Committee on Commerce, Science
and Transportation
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

Enclosed are the final responses to written questions resulting from the July 13, 1988, hearing at which Dr. Watson testified on global change research.

This material completes the information requested during that hearing.

Sincerely,

Mary D. Kerwin
Director, Congressional
Liaison Branch

Enclosure

Responses to Written Questions Submitted by Chrm. Hollings.

GLOBAL CHANGE RESEARCH

Question 1: The United States and more than 40 countries recently signed the Montreal Protocol on Substances that Deplete the Ozone Layer. Dr. Watson, you played a key role in highlighting the need for the Montreal Protocol and providing the scientific information the the Protocol's negotiators needed.

a) How well did scientists and policymakers work together during the negotiations that led to the Montreal Protocol?

b) What lessons were learned in Montreal about combining science and policy?

c) How important is it that researchers be perceived as being independent of policymakers and regulators?

d) Will scientists be involved in future follow-up negotiations to further reduce CFC production?

Answer 1a: I believe that during the period of negotiating the Vienna Convention for the Protection of the Ozone Layer, and the Montreal Protocol on Substances that Deplete the Ozone Layer, the interaction between the scientists and the policymakers was excellent at both the national and international level.

Although there was no formalized interagency mechanism to promote the exchange of scientific information between the scientific community and the policymakers in Washington D.C. the interaction worked well. Scientific agencies such as NASA and NOAA were invited to attend all interagency meetings while the U.S. position for the Vienna Convention and the Montreal Protocol was being formulated, in order to present the latest scientific information. Scientific briefings were also given to working groups of the Domestic Policy Council (DPC), and I gave a scientific briefing to the DPC prior to the final formulation of the U.S. position for the meeting in Montreal.

NASA and/or NOAA were nearly always invited to have an official member on the U.S. delegation for both bilateral and multilateral discussions and negotiations concerning both the Vienna Convention and the Montreal Protocol. In fact this model where the composition of the U.S. delegation contains both policy makers and scientists is one that should be followed in future bilateral and multilateral discussions and negotiations of issues such as ozone depletion and global warming.

During the international negotiations of both the Vienna Convention and the Montreal Protocol there were technical working groups of scientists, which I normally chaired, to write the scientific annexes and to present scientific information.

Significant use was made, both nationally and internationally, of the scientific assessments, including the NASA led comprehensive international assessments, the UNEP reports of the Coordinating

Committee on the Ozone Layer (CCOL), and UNEP meetings of scientific experts, e.g. the Wurtburg meeting of theoretical modelers.

Answer 1b: It is clear that the foundation for international policy decisions must be based on scientific assessments that are comprehensive and written by the broadest possible geographic spectrum of the international scientific community. Countries whose scientists were not involved in assessing the state of the scientific knowledge become skeptical of the scientific basis being used to formulate policy. In order to minimise such difficulties in the future there will be increased participation of scientists from the USSR, China, Japan, and the developing countries in the scientific assessments.

Answer 1c: It is absolutely essential that science and policy be independent. As soon as a scientist is viewed as being an advocate for a regulatory position their scientific credibility is questioned by those not holding the same views. The international scientific assessments which I have chaired have been coordinated by NASA, cosponsored by a number of other national and international scientific agencies, and written by the world's best scientists. These assessments have been widely accepted by the scientific community, governments, industry and environmental groups as being unbiased and as such have been used as the scientific basis for both national and international policy decisions. Scientific assessments conducted by regulatory agencies have often mixed scientific and policy issues, are often viewed as policy driven, and have not been widely accepted by the scientific community or other governments. I believe that it is essential that scientific assessements of issues of global significance are international, are written by the world's best scientists, and are coordinated by non-regulatory agencies. However, it is clearly recognized that the scope of the scientific assessments must meet the needs of the policy-makers.

It was quite clear during the negotiations of the Vienna Convention and the Montreal Protocol that when scientific statements were made by scientists who were members of national delegations they were, in most cases, viewed as being unaffected by that scientists delegations views on policy matters. It was vital that the scientific statements were factual and not used to support one policy over another.

Answer 1d: Yes. The Vienna Convention and the Montreal Protocol both recognize that the basis for all regulatory measures requires consideration of the latest scientific findings. Therefore, the Montreal Protocol requires that a scientific assessment be performed at four year intervals prior to any reassessment of regulatory measures. The first scientific assessment is scheduled to be completed by January 1, 1990. The U.S. has been requested by Dr. Tolba of the United Nations Environment Program (UNEP) to take responsibility for part of the assessment, namely an assessment of the current understanding of the physical and chemical processes that control the abundance and distribution of ozone. An "effects" assessment will also be performed, but not chaired from the U.S.

Prior to the comprehensive assessments there will be a UNEP meeting of scientific experts in Holland in October of this year to draft a summary of the current state of scientific understanding.

Question 2: Although scientists seem to agree that the greenhouse effect is a real phenomenon, I understand that there is some controversy over whether global warming has actually begun.

a) Is there clear, unequivocal data showing that global temperatures are increasing?

b) Can we be certain that these rising temperatures are a reflection of greenhouse warming?

Answer 2a: Yes. A number of scientists have separately analyzed the historic temperature records, both land-based and sea-based, and have independently concluded that the annual global temperature of the atmosphere has increased since the late 1800's by between 0.5 to 1.0 degree Centigrade. The data also clearly shows that the present global temperatures are the highest in the period of instrumental records with the four warmest years in the past century all occurring in the 1980s. While there are still questions concerning the accuracy and precision of this data, especially during the early period, the view of most scientists is that the data does provide evidence of an overall temperature increase. During the next couple of years a thorough reanalysis of all temperature data will be performed by a number of independent scientists from the U.S. and abroad.

Answer 2b: No. However, we should recognize that the overall magnitude of the observed increase in global temperatures since around the mid to late 1800's is consistent with that predicted from theoretical models because of the increased atmospheric abundance of radiatively active trace gases (greenhouse gases), primarily carbon dioxide. While there is consistency between the predicted change in global temperatures and that observed over the past century or so, we should be cautious in claiming an adequate understanding of the climate system before we can explain the step like changes in the temperature record from 1920 to the present. One scientist who has focussed on the last thirty years, where the temperature record is most reliable, reports that the observed and predicted temperature changes are quite consistent, however, to establish a causal relationship between the observed warming and the greenhouse gases requires a much better understanding of the sources of natural and anthropogenically forced variability.

In order to simulate how the Earth's climate may have changed during the past century or so requires an understanding not only of the forcing functions of the system which have been monitored, but of the planetary response processes. Natural forcing functions include changes in solar irradiance and changes in atmospheric composition due to volcanic erruptions, while anthropogenic forcing functions include increases in the atmospheric abundances of radiatively active trace gases and changes in land use and cover. Quantitative simulations of the observed temporal changes in climate requires an understanding of numerous processes including the cloud-albedo feedback, and the exchange of energy and trace gases at

the ocean-atmosphere interface. Significant uncertainty currently exists in our understanding of these and other processes.

While there is a spectrum of scientific opinion as to whether a causal link has yet been established between the the temperature record to date and the increased atmospheric abundances of greenhouse gases, most scientists believe that the inevitable consequence of the increasing trend in greenhouse gases is towards a global warming.

Question 3: I know that you have been involved with the research on the Antarctic Ozone Hole that determined that CFCs were causing it. I also understand that there's been some recent work on ozone depletion in the Arctic.

a) Based on your research, is there also an Arctic Ozone Hole? And does the preliminary data indicate that it is caused by CFCs?

b) Is ozone depletion over the Arctic as serious as that over Antarctica?

Answer 3a. There is no evidence of an Arctic ozone hole, but there is evidence that there has been a more modest depletion of ozone over a much larger area in the northern hemisphere, primarily in winter, which cannot be attributed to known natural variability.

The recent international Ozone Trends Panel concluded that:

* based on an analysis of data from ground-based Dobson instruments, after allowing for natural geophysical variability, total column ozone has decreased from 1969 to 1986 in the annual average by between 1.7 and 3.0 percent at latitudes between 30 and 64 degrees North;

* the decreases are most pronounced, and ranged from 2.3 to 6.2 percent, during the winter months (December through March, inclusive);

* the mean values of the observed decreases at mid and high latitudes in winter are larger than the mean values of the predicted decreases;

* the observed changes may be due wholly, or in part, to the increased atmospheric abundance of trace gases, primarily CFCs.

The evidence of a decrease in ozone at high latitudes in winter /spring from the ground-based Dobson network is supported by data from the Nimbus 7 Total Ozone Mapping Spectrometer (TOMS).

NASA, NOAA, NSF and the CMA will be conducting an intensive ballon, aircraft, and satellite campaign to understand the cause(s) of the observed ozone decreases in the northern hemisphere winter between January 1 and February 15, 1989. The aircraft will located in Stavager, Norway, and the campaign will be similar to that conducted from Punta Arenas, Chile in 1987 to study the Antarctic Ozone Hole.

Answer 3b: Ozone depletion is always serious. The magnitude of ozone depletion over the Arctic in winter (about 6 percent since 1969) is significantly less than that observed over the Antarctic in springtime (more than 70 percent since 1979). It should be noted that the reported ozone loss at mid and high latitudes does occur in winter when the amount of ultraviolet radiation reaching the ground is quite low, and not in the spring and summer months during the growing season of most plants and when humans sunbathe. Given that we have not yet demonstated the cause of the depletion we do not know quantitatively how ozone may change in the future in the northern hemisphere. We must remember that a great proportion of the world's population lives in the northern hemisphere at mid to high latitudes and therefore the potential consequences of a significant ozone depletion are considerable.

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